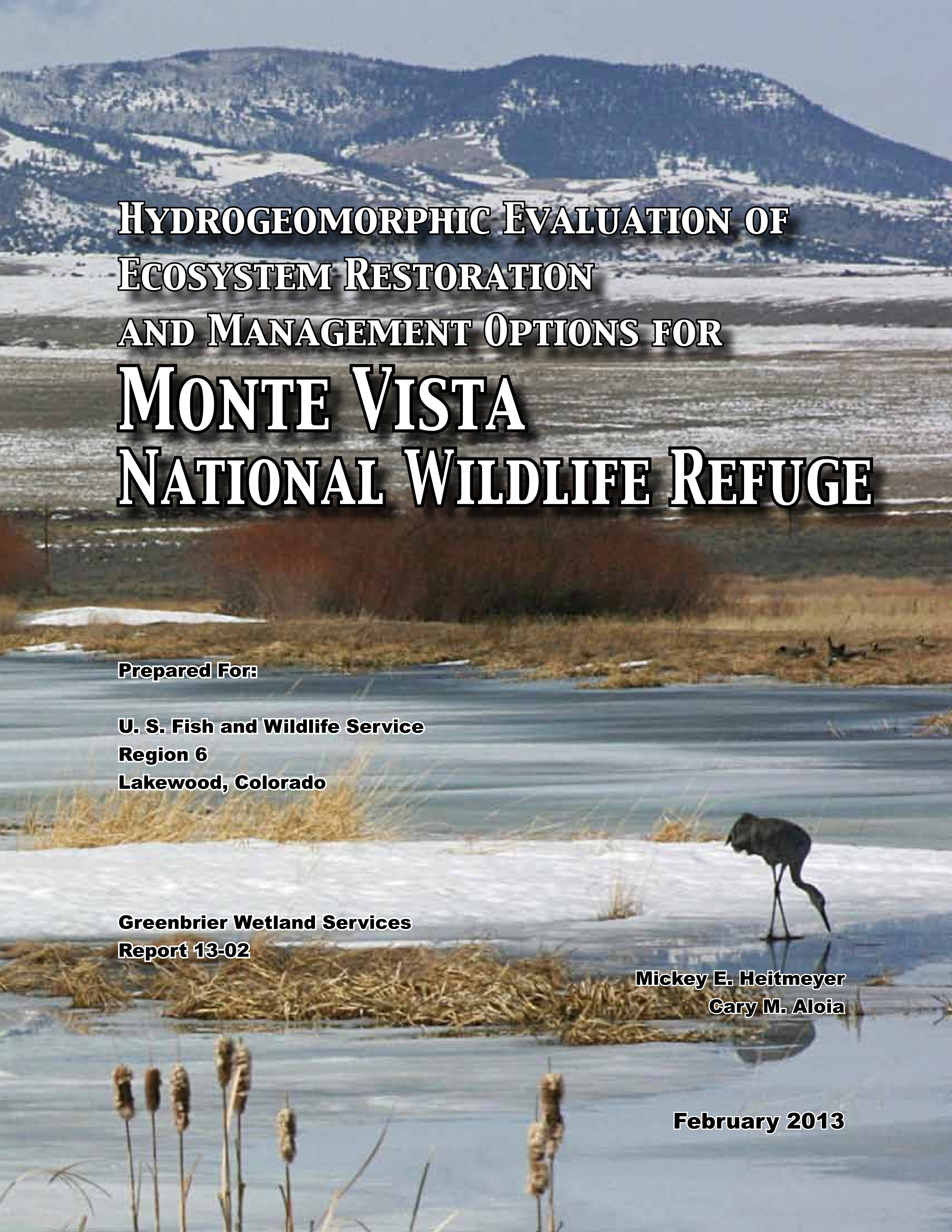

Hydrogeomorphic Evaluation of Ecosystem Restoration and Management Options for

Monte Vista National Wildlife Refuge

Prepared For:

U. S. Fish and Wildlife Service
Region 6
Lakewood, Colorado

Greenbrier Wetland Services
Report 13-02

Mickey E. Heitmeyer
Cary M. Aloia

February 2013

HYDROGEOMORPHIC EVALUATION
OF
ECOSYSTEM RESTORATION
AND MANAGEMENT OPTIONS
FOR
MONTE VISTA NATIONAL WILDLIFE REFUGE

Prepared For:

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EXECUTIVE SUMMARY

This report provides a hydrogeomorphic (HGM) evaluation of ecosystem restoration options to assist future management of the Monte Vista National Wildlife Refuge (NWR) located in the San Luis Valley (SLV) of south-central Colorado. Monte Vista NWR contains 14,800 acres and was established in 1952. The refuge is located at the base of the San Juan Mountain foothills immediately south of where the Rio Grande enters the SLV. Most of the refuge lies on the large Rio Grande alluvial fan and three creek drainages (Spring, Rock, and Cat) bisect the area. Historically, the alluvial fan area was dominated by an extensive salt desert shrub community and wetlands were located along the creek corridors. The foothills of the San Juan Mountains on the far west side of the refuge historically contained undershrub grasslands.

The SLV is a highly modified region. Major ecological changes in the SLV began in the mid-1800s when agricultural production expanded and extensive irrigation systems were constructed to divert Rio Grande river water, pump groundwater from shallow unconfined and deeper confined artesian sources, and move water through an elaborate system of ditches and canals to upland areas. Over time, most native vegetation communities in the SLV were converted to agricultural production and current water use in the valley is tightly regulated and becoming more limited. Early landscape changes to the Monte Vista NWR lands were further modified after refuge establishment, primarily to increase flooded areas of wetlands and meadows. While this development was beneficial to certain species in some seasons, including breeding dabbling ducks, the long-term consequences of water diversion and seasonal inundation of areas formerly in shrub habitat have included increased soil salinity, shifts in native vegetation species distribution, altered resource availability to native animal species, and invasion and establishment of non-native plant species, especially tall whitetop (*Lepidium latifolium*).

In 2003, a Comprehensive Conservation Plan (CCP) was prepared for Monte Vista NWR and the nearby Alamosa NWR to identify habitat and public use goals. Since that time, management has sought to implement CCP goals, but also has recognized the need for more holistic system-based approaches to future restoration and management strategies. In 2011, a new CCP planning process for SLV NWRs, including Monte Vista NWR, was initiated and this planning is being facilitated by Hydrogeomorphic Methodology (HGM). The HGM process obtains and collates historical and current information about: 1) geology and geomorphology, 2) soils, 3) topography and elevation, 4) hydrology, 5) aerial photographs and maps, 6) land cover and plant/animal communities, and 7) anthropogenic features of ecosystems.

This report provides HGM evaluation of Monte Vista NWR with the following objectives:

1. Identify the Presettlement ecosystem condition and ecological processes in the Monte Vista NWR region.
2. Evaluate differences between Presettlement and current conditions in the Monte Vista NWR ecosystem with specific reference to alterations in hydrology, vegetation community structure and distribution, and resource availability to key fish and wildlife species.
3. Identify restoration and management approaches and ecological attributes needed to successfully restore specific habitats and conditions within the Monte Vista NWR region.

The dominant geological feature of Monte Vista NWR is the large alluvial fan formed where the Rio Grande enters the SLV. This fan is Quaternary-age and three creeks that originate from the San Juan Mountains flow across the fan. About 30 distinct soil types are present on Monte Vista NWR and three general soil associations define geomorphology and topography. The alluvial fan is dominated by Hooper-Arena-San Luis Association soils formed in mixed alluvium. Torrifluvent-Torsido-Alamosa Association soils occur in historic floodplains of the three creeks on the refuge. San Juan Mountain foothills contain Luhon-Garita-Travelers Association soils; these are well drained coarse texture materials formed in mixed erosional alluvium and weathered basalt residuum. The topography of the refuge largely reflects the transition from foothill to alluvial fan surfaces and the bisection of narrow creek corridors. Few natural "wetland" depressions exist on the refuge and historical maps show these areas primarily along Rock Creek in the north-central part of the refuge.

The climate of the SLV is arid, with cold winters and moderate summers. Monte Vista NWR is in the pronounced rain shadow of the San Juan Mountains and receives an average of about seven inches of precipitation per year; about 60% of this precipitation is rain in July and August. Long-term precipitation data from Del Norte, west of Monte Vista NWR, indicates annually dynamic patterns with frequent switches between dry (< 6 inches) to wet (> 12 inches) years. Historically, Monte Vista NWR received annual inputs of surface water primarily from the limited onsite precipitation during summer and surface water drainage from Rock, Spring, and Cat creeks. Rock Creek historically was fed primarily by snowmelt and subsurface drainage helped maintain some creek baseflow. Spring Creek, as its name implies, historically was fed by a relatively large groundwater discharge "spring head" located in the southwest corner of Monte Vista NWR. Cat Creek originated in the San Juan Mountain foothills and apparently had intermittent flow that terminated on the alluvial fan of the refuge. The refuge area did not receive surface water flooding from the Rio Grande.

Vegetation in the SLV historically was highly influenced by the relatively low, but intense, amounts of summer rainfall and most annual plants germinate and grow, and most perennial plants flower, during late summer. The surface soils outside of creek areas on Monte Vista NWR usually are dry until early summer and even if soils are not dry, the cold spring temperatures prevent plant germination until June. The undershrub grasslands historically present on the San Juan Mountain foothills are dominated by grama-type grasses with some intermixed shrubs. This grassland community transitions to salt desert shrub on the Rio Grande alluvial fan and throughout the floor of the SLV. Scattered sagebrush (*Artemsia tridentata*) historically was present in transition areas between grassland and salt desert shrub and shrublands were dominated by greasewood (*Sarcobatus vermiculatus*), rubber rabbitbrush (*Ericameria nauseous*), shadscale, commonly called fourwing saltbush (*Atriplex canescens*), alkali sacaton (*Sporobolus airoides*), and saltgrass (*Distichlis spicata*). Soils in salt desert shrub areas typically are poorly drained and groundwater tables historically were close to the ground surface. Even slight differences in elevation of a few inches can alter drainage and cause ephemeral ponding, which creates higher salinity and heterogeneity in plant distribution. When alkali is high, "chico slick spots" occurs as barren salt flats.

The relatively narrow creek corridors on Monte Vista NWR include active and relict creek channels and associated narrow floodplains. Historically, wetland depressions typically had seasonal flooding regimes and supported diverse sedges, rushes, and herbaceous wetland species. A few deeper areas may have supported persistent emergent species such as cattail (*Typha spp.*) and softstem bulrush (*Sciprus validus*). Vastine soils are the most common soil type associated with historic distribution of wetlands on Monte Vista NWR. The edges of creek channels included a marginal wet meadow zone that contained diverse sedges and rushes. These meadows extended away from stream bank zones in some areas. Riparian trees were limited, if present at all, along creeks.

An HGM matrix of the relationships between major plant communities and a combination of geomorphic surface, soil, topography and hydrology attributes was developed to prepare a map of potential distribution of historical communities on Monte Vista NWR. The major factors influencing vegetation distribution were: 1) geomorphic surface and topographic position, 2) soil salinity, and 3) onsite hydrology that was affected by seasonally and annually variable inputs of water and whether the site was subirrigated by high groundwater tables.

Many studies and reports have documented the extensive land use changes in the SLV, mostly associated with the development of elaborate irrigation capacity to support regional agricultural production. The first ditch to move water from local rivers to the interior of the SLV was the San Luis Peoples Ditch constructed in 1852. The “Ditch Boom” exploded in the 1880s and major canals that affect Monte Vista NWR including the Empire and Monte Vista Canals were built at that time. Agricultural production in the SLV was further enhanced by drilling thousands of wells into both the shallow unconfined and the deeper confined aquifers starting in the late-1800s. By 1980, about 2,300 pumped wells existed in the unconfined aquifer and over 7,000 wells tapped deeper artesian groundwater sources. At Monte Vista NWR, many areas of former salt desert shrub lands on higher elevation alluvial fans near creek channels were converted to annually irrigated wet meadows for livestock grazing and cropland production using irrigation infrastructure built in the late-1800s and early-1900s. Much of this early water-control infrastructure remains present on the refuge.

Immediately prior to refuge establishment in 1952, the Monte Vista NWR area was predominantly pasture/hay and cropland. The original development plan for the refuge proposed considerable expansion of existing ditches, dikes, drains, water-control structures and roads to increase the diversion of water from the Monte Vista and Empire Canals to enhance existing, and create new, irrigated meadows and wetland ponds. The subsequent development of extensive water diversion and storage infrastructure subdivided the refuge into more than 80 sub-units. Certain units on Monte Vista NWR have been extensively developed and compartmentalized by relatively large angle-dikes (e.g., Units 6, 10, 15, 16, 19), closely-spaced contour levees (Units 7 and 9), and conveyance ditches (Units 15, 16, 6, 8, 10). Many of these water-diversion/control developments have effectively blocked, diverted, and significantly modified former natural surface water flow pathways and patterns and have attempted to create meadow and wetland habitats in areas that formerly were salt desert shrub habitat. Modification of natural surface flow pathways occurs throughout the Spring and Rock Creek drainage corridors in Units 1-11, 14, and 15 and within the smaller formerly intermittent flow corridor of Cat Creek in Units 16, 17, and 22.

In the early-1950s, all of the wells on Monte Vista NWR were free-flowing from artesian pressure in the deeper confined aquifer and Spring Creek was still discharging groundwater. However, by the 1970s, the Spring Creek groundwater "spring head" stopped flowing and the number of free-flowing artesian wells on the refuge declined greatly. Currently, during summer months almost all artesian wells on Monte Vista NWR cease flowing when maximum groundwater pumping occurs on and off the refuge for irrigation purposes. Currently, Monte Vista NWR has 254 wells that historically provided at least some water to the refuge. Water from these wells is adjudicated for irrigation, wildlife, domestic and stock water purposes.

Water availability and management at Monte Vista NWR is heavily controlled by SLV-wide water diversion infrastructure and associated Rio Grande Compact and water rights law. Monte Vista NWR receives an annual average of about 8,500 acre-feet of irrigation water from the Rio Grande primarily through the Empire and Monte Vista canals and from water draining neighboring private lands into several drainage ditches (e.g., Parma and Bowen drains). The water delivery and diversion to the more than 80 wetland management sub-units on Monte Vista NWR is achieved using the complex infrastructure that includes more than 30 major and 100 minor dikes, over 400 water-control structures ranging from road culverts to larger creek dams and diversion points, and 61 miles of ditches.

Early in the development of Monte Vista NWR, over 100 small (1/4- to one-acre) "ponds" were created by constructing ring-dikes around artesian wells that were present when the property was purchased by the USFWS. These ponds were intended to capture and hold artesian well water and provide small wetlands for waterfowl and other local wildlife species. Many of these ponds were not capable of holding water for more than short periods, because of low artesian flow and porous soils. The soil salinity of some pond sites also was high. Currently, many of these ponds are dysfunctional. As some small artesian wells quit discharging water, other deeper and bigger wells were drilled. More than 100 islands were built in wetland units for nesting waterbirds and ducks.

Annual narratives for Monte Vista NWR chronicle the many water and habitat management activities on the refuge through 1994. Management on the refuge is designated by 24 major management or "administrative" units and since the early-1960s management has focused on providing habitat for breeding ducks, which included early annual flooding, planting and maintaining dense nesting cover, and some predator control. This management emphasis was fostered by the attraction of high numbers and densities of breeding dabbling ducks to flooded wetlands on the refuge. Long-term studies of nesting ducks on the refuge indicated generally good nesting success and recruitment of young from the refuge into the 1990s.

Water management on Monte Vista NWR has been generally consistent over the past 30+ years based on refuge annual narratives. The extensive development of wetland management infrastructure before and after refuge establishment, the relatively consistent annual water regime management (flooding) among management units, and clearing of shrubland for croplands greatly altered the vegetation community/habitat composition on Monte Vista NWR since its establishment. Major modifications/degradations included a major reduction in the extent and composition of salt desert shrub habitat and a shift in remnant shrubland community composition toward the invasive weed, tall whitetop, and wetland vegetation, especially Baltic rush (*Juncus balticus*). Currently about 24% of the refuge is in salt desert shrub habitat, which when compared to the potential historic vegetation represents a decrease of about 67% of this community type over time.

The extensive spread of tall whitetop on Monte Vista NWR is closely associated with the disturbance of soils and changes in hydrology caused by artificial irrigation and diversion of water to former shrublands. Although initially spread through the ditch system, native shrub vegetation communities were converted to wetter states through prolonged seasonally flooded hydrologic regimes, which allowed tall whitetop to out-compete natives. About 80%+ of the tall whitetop present on Monte Vista NWR is associated with levees and ditches or has spread over time from these points to interior areas. Refuge management has attempted to limit the spread of invasive plant species, especially tall whitetop, using repeated mowing, herbicide application, and targeted grazing using sheep in some areas.

This HGM report provides information to help identify general options for restoration of native ecosystems on Monte Vista NWR if that is a future strategic conservation goal. Assuming this goal, the paramount issue influencing future restoration and management success is the need to change how management addresses the timing, distribution and movement of water on the refuge. General recommendations to address critical water issues include:

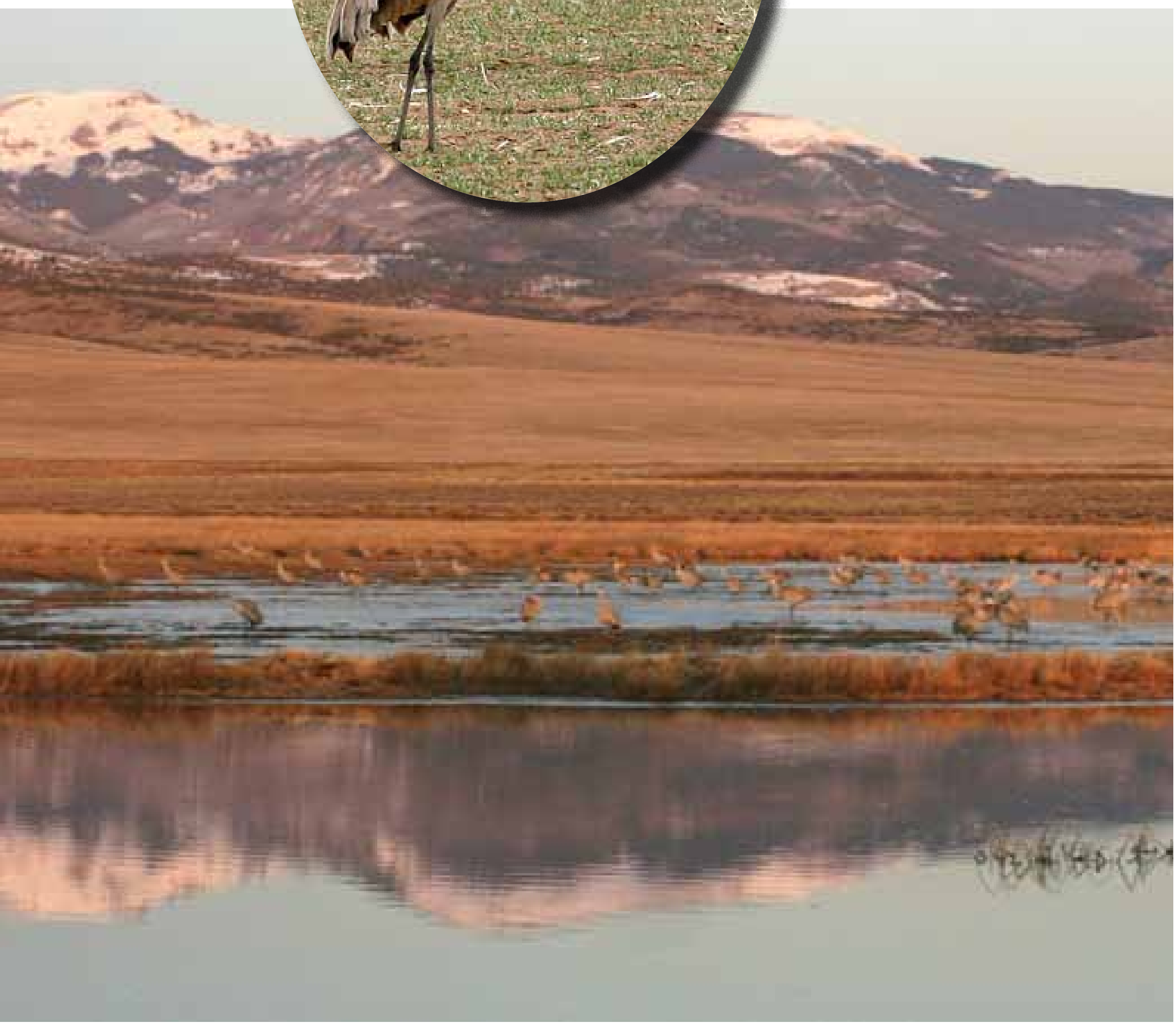
1. Restore natural surface water flow pathways and associated hydrological regimes where possible to restore and manage wetlands and wet meadows along Spring, Rock, and Cat Creeks.
2. Restore natural topography and promote natural hydrologic regimes to restore at least some areas of historically occurring salt desert shrub and undershrub grassland habitat including its natural heterogeneity of sub-habitat components.
3. Restore natural disturbance regimes such as herbivory, fire, and drought to promote the health and quality of all habitat types and reduce noxious weeds.

Specific recommendations to implement each of the above general goals are provided in the report. For recommendation #1, future water management at Monte Vista NWR should consider changes in water-control and water diversion infrastructure and refuge management strategies to more closely emulate natural flow patterns, distribution, and seasonal/long-term dynamics of surface and subsurface water to reinstate appropriate historical distribution of communities, especially wetland and wet meadow habitats, improve native plant species diversity and productivity, reduce alkali concentrations, and increase efficiency of total water use. Itemized recommendations are provided to restore the Cat Creek drainage, remove ring-dikes, restore flow in the natural Rock and Spring Creek drainages, modify and remove certain water-control infrastructure, restrict prolonged flooding in soils historically dominated by shrubs, manage water regimes in former wet meadow sites, vary annual flooding regimes among years, remove many wetland sub-units, and prevent conversion of former wet meadow and salt desert shrub areas to seasonal or semipermanent wetlands.

For recommendation # 2, restoration of salt desert shrub and undershrub grassland should be carefully targeted to former occupancy sites. Itemized recommendations are provided to target salt desert shrub to former distribution especially where some shrubland still exists, remove water-control infrastructure and restore natural topography and overland sheetflow of water in historic shrub areas, remove ring-dikes and decommission small flow artesian wells, restore natural hydrological regimes in shrublands by changing irrigation and flooding to spring periods, protect foothill areas from additional physical alteration, remove roads that alter natural water flow and that cause impoundment of water, and remove water-control structures in former shrublands that are no longer used.

For recommendation #3, natural disturbance regimes should be reintroduced and managed where possible. Itemized recommendations are provided to investigate the historical occurrence of disturbance events, attempt late winter burns if fire can be used, consider methods to remove residual vegetation in wetland and wet meadow habitats, mow or hay if natural herbivory is not an option, encourage overbank flood events on creeks, promote periodic drought in shrublands and current tall emergent wetland habitats, and control invasive species using a combination of treatment methods.

Future management of Monte Vista NWR will benefit from continued key monitoring studies and directed studies as needed. Future management also can be conducted in an adaptive management framework. Specific information needs for the refuge are related to ground and surface water quality and quantity, efforts to restore natural water flow patterns and water regimes, and long-term changes in vegetation and animal communities.



INTRODUCTION

Monte Vista National Wildlife Refuge (NWR) contains 14,800 acres on the west side of the San Luis Valley (SLV) in south-central Colorado (Fig. 1). The refuge was established in 1952 under the authority of the Migratory Bird Treaty Act in response to local interest in protecting wintering duck habitat along Spring Creek and reducing waterfowl depredation on nearby privately owned grain fields (U.S. Fish and Wildlife Service (USFWS) 2003). The authorizing purpose of the refuge was "… for use as inviolate sanctuary or for any other management purpose, for migratory birds." Acquisition of lands for a NWR in the region was considered as early as 1941, when a refuge to be named "Spring Creek NWR" was initially discussed by the USFWS. In August 1949 a potential refuge boundary (with a name change to "Monte Vista NWR") that encompassed about 13,475 acres was officially proposed (Hise 1994). The first funds for acquiring the refuge were made available in 1951-52; thereafter fee-title acquisition of private lands and withdrawal of public lands administered by the U.S. Bureau of Land Management (BLM) eventually created the current refuge size.

Monte Vista NWR is located at the base of the San Juan Mountain foothills immediately south of where the Rio Grande enters the SLV. The entry of the Rio Grande into the SLV historically created a large elevated alluvial fan, on which Monte Vista NWR sets (Fig. 2, Bachman and Mehnart 1978). Monte Vista NWR is bisected by three creek drainages (Spring, Rock, and Cat Creeks) that originate in the San Juan Mountains. Historically, the alluvial fan at Monte Vista NWR was dominated by an extensive salt desert shrub community, with wetlands located in the relatively narrow creek drainage corridors (Ramaley 1942). The foothills of the San Juan Mountains on the far west side of the refuge contained "undershrub" grasslands. The combination of grassland, shrub, and

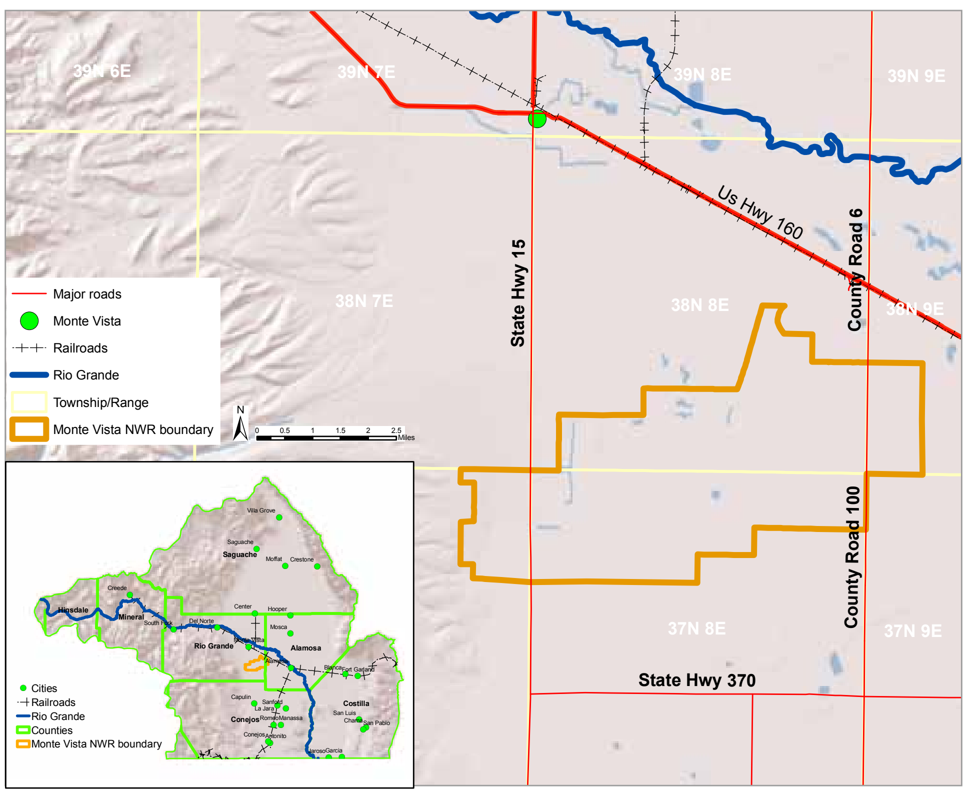


Figure 1. General location of Monte Vista National Wildlife Refuge.

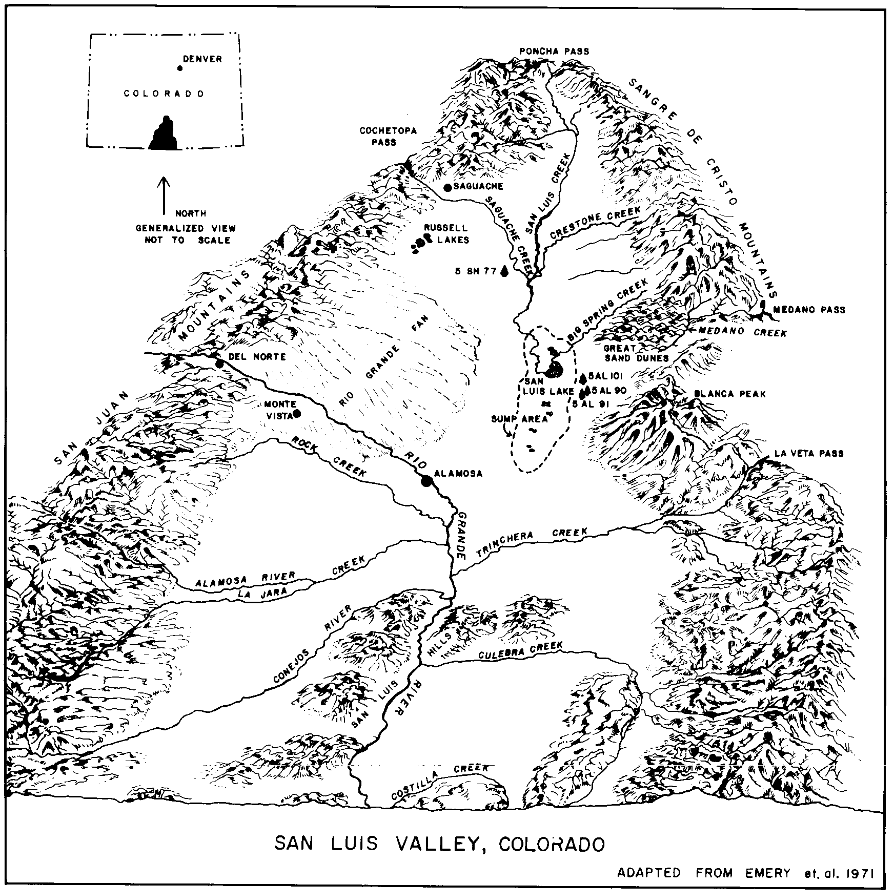


Figure 2. Physiography of the San Luis Valley showing the location of the Rio Grande and Rock Creek alluvial fans (modified from Jodry and Stanford 1996).

wetland communities provided important resources for many diverse animal species (USFWS 2003).

Many land and water use changes have occurred in the SLV and at Monte Vista NWR since European settlement. Following major expansion of settlements in the SLV during the mid-1800s, agricultural production became the predominant way of life for local residents, but was limited by the availability of surface and groundwater. To support a growing agricultural economy, irrigation "systems" were extensively developed in the SLV and included diversion of water from the Rio Grande and other rivers/creeks, conveyance of diverted water through an elaborate system of ditches and canals, exploitation of groundwater using pumped wells from shallow unconfined aquifers and from free-flowing and pumped deeper artesian water, and various use and diversion of prior-used "drainwater" (see Buchanan 1970, Athearn 1975, Hanna and Harmon 1989, Emery 1996 and others). Use and allocation of both surface and groundwaters now is regulated through many complex water rights, the Rio Grande Convention Treaty of 1906 and later interstate "Compact" agreements, state and local irrigation districts, and individual water source/diversion legalities. Over time, water availability for wetland management on Monte Vista NWR has become limited because of reduced natural river and stream flows, decreases in groundwater levels and discharges, climatic conditions, and many other local and SLV-wide water and land use issues (Emery et al. 1973, Cooper and Severn 1992, Ellis et al. 1993, Emery 1996, refuge annual narratives). For example, by the late-1970s, groundwater in the region had declined to such an extent that groundwater discharge flows in Spring Creek, which formerly flowed through Monte Vista NWR, ceased (USFWS refuge annual narratives). Future efforts to regulate over-appropriated and limited groundwater in the SLV (and the entire Rio Grande system) is being driven by the Colorado State Engineer through promulgation of Groundwater Rules and Regulations, which will incorporate among other stipulations, the development of an "Augmentation Plan" that undoubtedly will place even greater limitations on water use for the refuge.

In addition to the extensive alterations in land and water uses in the larger SLV region, the USFWS also extensively modified landform and water distribution on Monte Vista NWR after it was established. These modifications included the construction of extensive water management infrastructure consisting of levees, ditches, and water-control structures and the conversion of former salt desert shrub communities to seasonally irrigated and inundated meadows and artificial wetlands (USFWS 1962, 2003). After the first 10+ years of water diversion management on Monte Vista NWR, which had emphasized annual diversion of surface water to shallowly flood wet meadow and former shrubland areas, large numbers of breeding ducks were attracted to the refuge and management priorities changed from maintaining wintering habitat and preventing depredation to active efforts to increase duck and waterbird production (Gilbert et al. 1996, USFWS 2003). The ecological consequences of long-term diversion of water and seasonal inundation of extensive areas formerly in salt desert shrub habitats have included increased soil salinity in many former shrub areas, shifts in the distribution of native vegetation species, altered resource availability to native animal species, and invasion and establishment of non-native plant species, especially tall whitetop (*Lepidium latifolium*). Monte Vista NWR also has been subject to management constraints from legal actions. For example, Monte Vista NWR was included in a lawsuit filed by the National Audubon Society in 1992 that alleged incompatible uses because of the refuge use of livestock grazing in habitat management. In 1993 the USFWS settled the lawsuit with the plaintiffs out-of-court through an agreement that specified actions for future management of the refuge.

In 2003 a Comprehensive Conservation Plan (CCP) was prepared for Monte Vista NWR and the nearby Alamosa NWR to identify habitat and public use goals (USFWS 2003). Since that time, management has sought to implement CCP goals, but also recognized constraints of water availability and quality and the need for more holistic system-based approaches to future restoration and management efforts. In 2011 the USFWS initiated a new CCP planning process for SLV NWR's, including Monte Vista NWR. This new CCP effort recognizes the need for more holistic system-based approaches to future restoration and management efforts and it is being facilitated by Hydrogeomorphic Methodology (HGM) evaluation. Recently, HGM has been used to evaluate ecosystem restoration and management options on many NWR's (e.g., Heitmeyer et al. 2009, Heitmeyer et al. 2010, Heitmeyer et al. 2012, Heitmeyer and Aloia 2013). The HGM process obtains and collates historical and current information about: 1) geology and geomorphology, 2) soils, 3) topography and elevation, 4) hydrology, 5) aerial photographs and maps, 6) land cover and plant/animal communities, and 7) physical anthropogenic features of ecosystems (Heitmeyer 2007, Klimas et al. 2009, Theiling et al. 2012, Heitmeyer et al. 2013). HGM information provides a context to understand the physical and biological formation, features, and ecological processes of lands within a NWR and surrounding region. This historical assessment provides a foundation, or baseline condition, to determine what changes have occurred in the abiotic and biotic attributes of the ecosystem and how these changes have affected ecosystem structure and function. Ultimately, this information helps define the capability of the area to provide key ecosystem functions and values and identifies options that can help to restore and sustain fundamental ecological processes and resources.

This report provides HGM evaluation of Monte Vista NWR with the following objectives:

1. Describe the pre-European settlement (hereafter Presettlement) ecosystem condition and ecological processes in the Monte Vista NWR region.
2. Document changes in the Monte Vista NWR ecosystem from the Presettlement period with specific reference to alterations in hydrology, vegetation community structure and distribution, and resource availability to key fish and wildlife species.
3. Identify restoration and management options and ecological attributes needed to restore specific habitats and conditions within the Monte Vista NWR region.

THE HISTORICAL MONTE VISTA ECOSYSTEM

GEOLOGY AND GEOMORPHOLOGY

The SLV is the largest of a series of high-altitude, intermontane basins located in the Southern Rocky Mountains (Jodry and Stanford 1996). The SLV is part of the much larger Rio Grande Rift Zone that extends from southern New Mexico north through the SLV to its northern terminus near Leadville, Colorado (Chapin 1971, Bachman and Mehnart 1978). The SLV Basin is a compound graben depression that was down-faulted along the base of the Sangre de Cristo Mountains, which resulted from extensive block faulting during the Laramide Orogeny. The western side of the SLV, close to Monte Vista NWR, is bounded by the San Juan Mountains, which was created by extensive Tertiary volcanism about 22 to 28 million years before the present (BP) (McCalpin 1996). The Oligocene volcanic rocks of the San Juan Mountains slope gradually to the SLV floor where they are interbedded with alluvial-fill deposits (BLM 1991).

From the Pliocene to middle Pleistocene time, a large, high altitude lake, Lake Alamosa, occupied most of the SLV (Machette et al. 2007). This ancient lake accumulated sediments that are designated as the Alamosa Formation (Siebenthal 1906, 1910). Lake Alamosa existed for about three million years before it overtopped a low wall of Oligocene volcanic rocks in the San Luis Hills and carved a deep gorge that flowed south into the Rio Grande, entering at what is now the mouth of the Red River. Monte Vista NWR apparently was never within the ancient Lake Alamosa basin proper, but was near its western edge (Fig. 3). Santa Fe Pliocene and Miocene formations underlie the Alamosa Formation, which is in turn underlain by Echo Park alluvium and then Precambrian rocks (Fig. 4).

The Rio Grande enters the SLV near Del Norte, Colorado and flows to the southeast just northeast of Monte Vista NWR. The entry of the Rio Grande into the SLV created a large, low elevation, alluvial fan that extends south of Monte Vista, Colorado (Fig. 2). This fan is characterized as Quaternary-age younger alluvium with surficial deposits (Fig. 5) that overlie older Pleistocene Alamosa Formation coalescing alluvial fans and moderately well-sorted fluvial deposits near the valley margins that adjoin the San Juan Mountains (Fig. 3). Drainages including Rock, Spring, and Cat Creeks that originate from the San Juan Mountains historically flowed across Monte Vista NWR and deposited erosional sediments throughout their narrow floodplains (Fig. 6). A small alluvial fan created by the entry of Rock Creek onto the larger Rio Grande alluvial fan covers the western boundary of the Monte Vista NWR (Fig. 2). Another alluvial fan along the Alamosa River is present immediately to the south of Monte Vista NWR (MWH et al. 2005).

SOILS

About 30 distinct soil types are present on Monte Vista (Fig. 7). The distribution of soil series on Monte Vista NWR reflects the three major landforms of the region: the San Juan Mountain foothills, the large Rio Grande alluvial fan, and Spring, Rock, and Cat Creeks and associated floodplains. Soils generally are dominated by loamy sands, which cover much of the former salt desert shrub areas present on the Rio Grande alluvial fan (U.S. Department of Agriculture Soil Conservation Service) (SCS 1980). Some heavy loam and clay loam soils are present on Monte Vista NWR and indicate the presence of former wetland areas (SCS 1980). Cobbled and gravelly loams are present along relict stream courses and terrace edges.

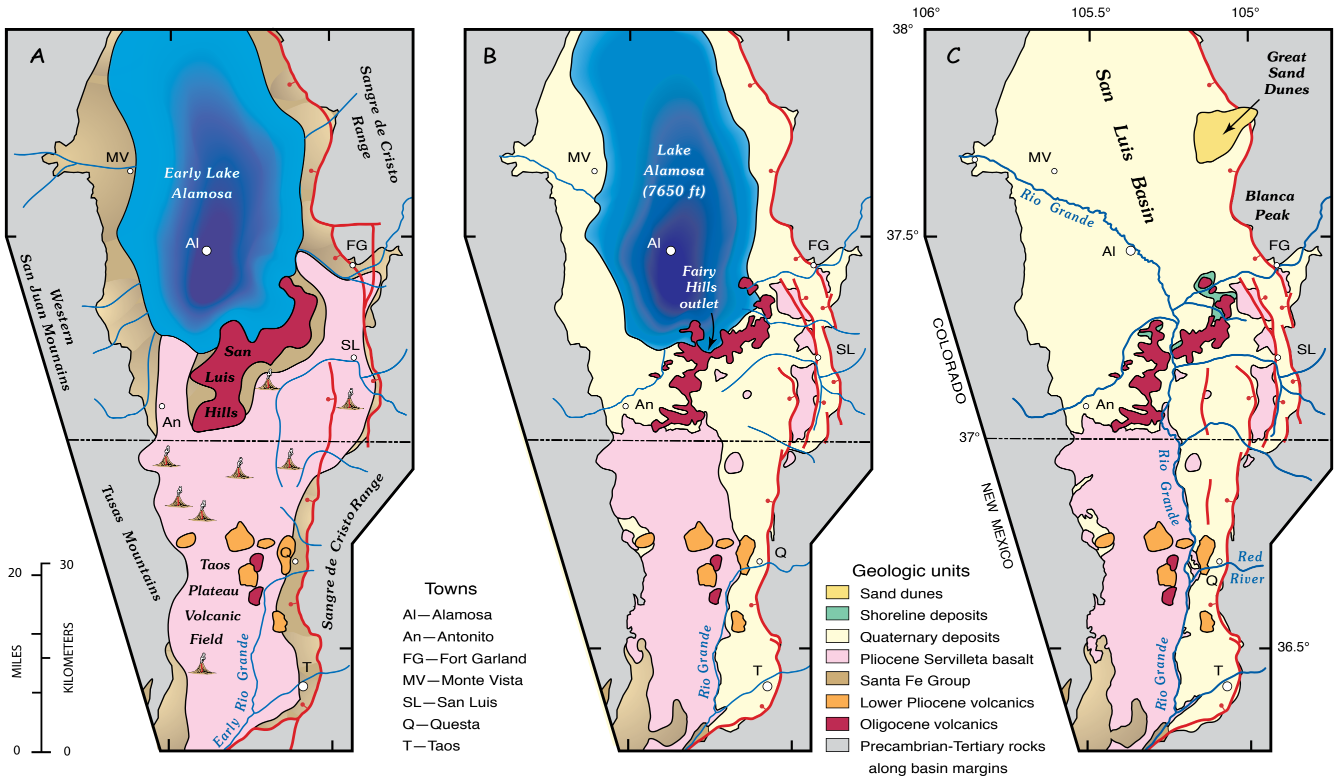


Figure 3. Simplified geological map of the San Luis Basin showing generalized geology and drainage patterns for the time intervals, A) 3.5-5 million years before the present (BP), B) 440,000 years BP, and C) current (from Machette et al. 2007).

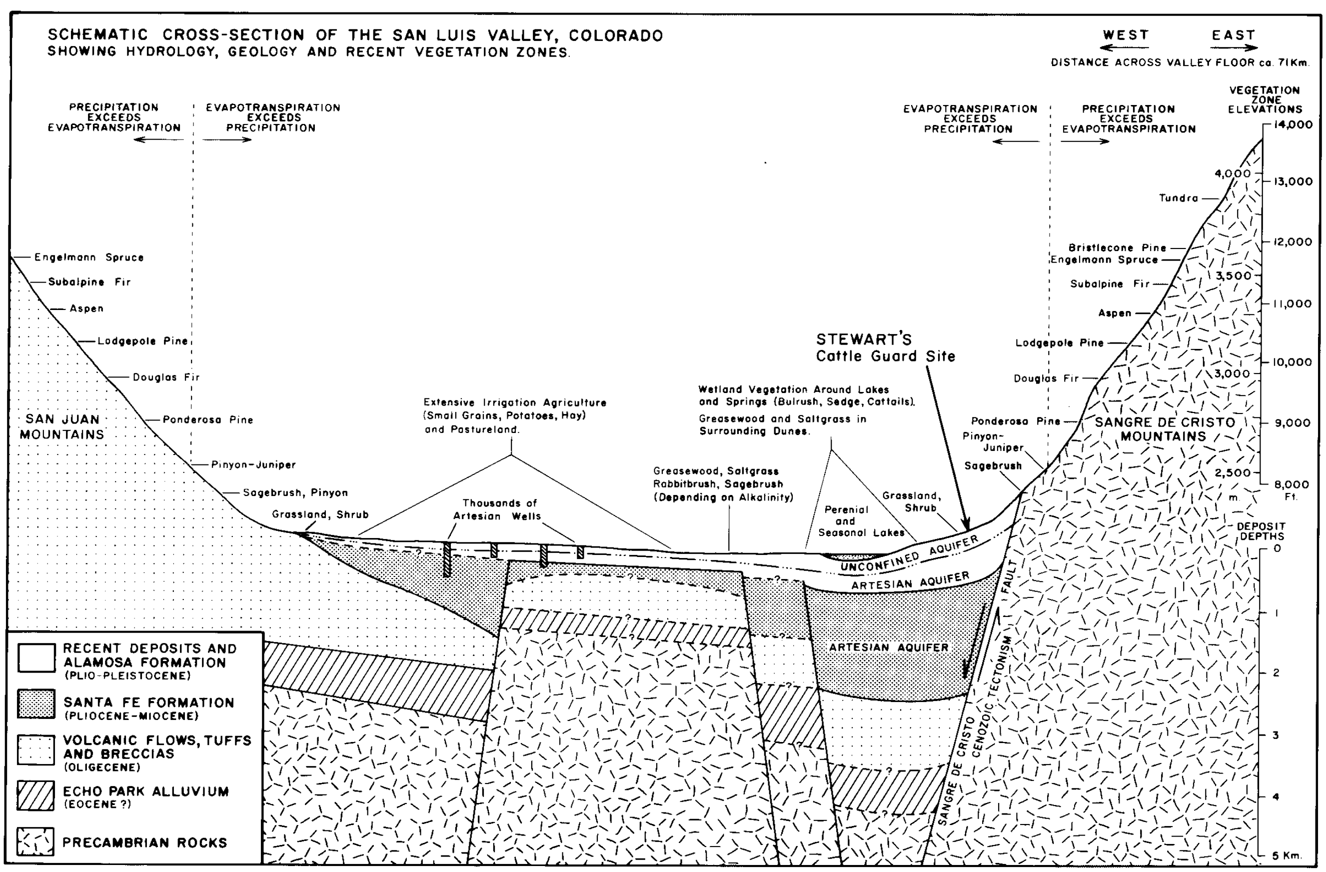


Figure 4. Schematic cross-section of the San Luis Valley (from Jodry and Stanford 1996).

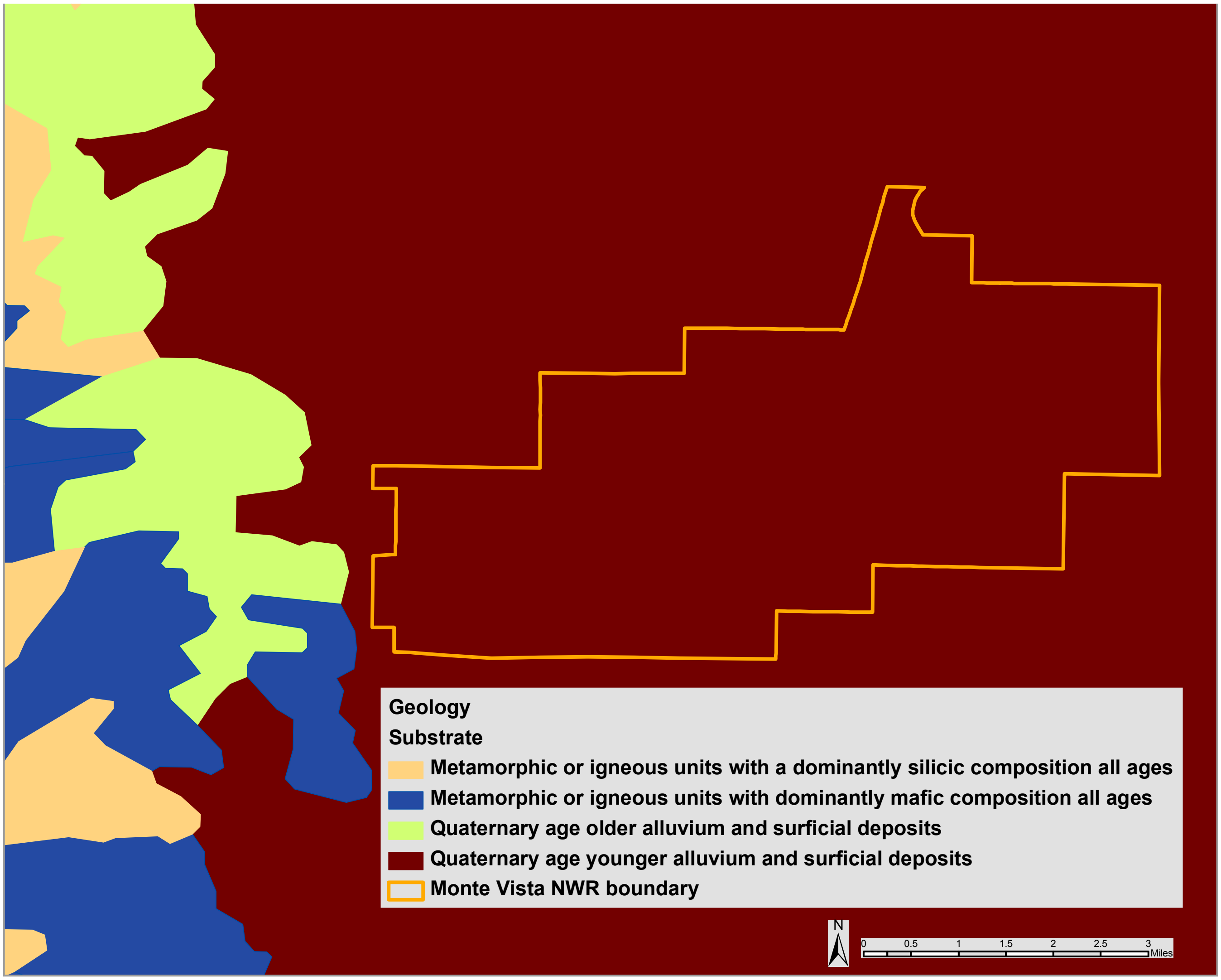


Figure 5. Surficial geology of the Monte Vista National Wildlife Refuge region (from USDA, Natural Resource Conservation Service, DataGateway site).

The San Juan Mountain foothills on the far west side of the refuge contain Luhon-Garita-Travelers Association soils (SCS 1980). These soils are well drained with coarse texture soils formed in mixed erosional alluvium and weathered basalt residuum. The Rio Grande alluvial fan is dominated by Hooper-Arena-San Luis Association soils; these soil types cover more area than other types on the refuge and are relatively flat (Table 1, SCS 1980). Hooper-Arena-San Luis soils were formed in mixed alluvium, often are alkaline, and contain loams about 20-60 inches deep that are underlain by sand and gravel layers. Alamosa loam, Gunbarrel loamy sand, San Arcacio sandy loam, Space City loamy sand, and Villa Grove sandy clay loam soils all have saline features. Torrifluvent-Torsido-Alamosa Association soils are intermingled on the refuge and formed in mixed alluvium. These soils occur in the historical floodplains of the small creeks on the refuge where surface water accumulated and deposited moderately-coarse to moderately-fine texture materials. These relict floodplain soils typically occur in depths of 10 to 60 inches over sand and gravel. Vastine clay loam soils reflect the presence of former wetlands that apparently had regular flooding based on redoxic features of the soil strata (SCS 1980). Vastine soils cover about 5.7% of Monte Vista NWR and are primarily mapped downstream of the confluence of the former Rock and Spring Creek channels; these soils provide a relative indication of the extent and distribution of more frequently inundated wetland locations on refuge lands. Acasco (4.0%), Torsido (3.5%), Mishak (1.5%), Alamosa (0.4%), and Typic fluvaquents (0.1%) soils total about 9.5% of Monte Vista NWR and indicate

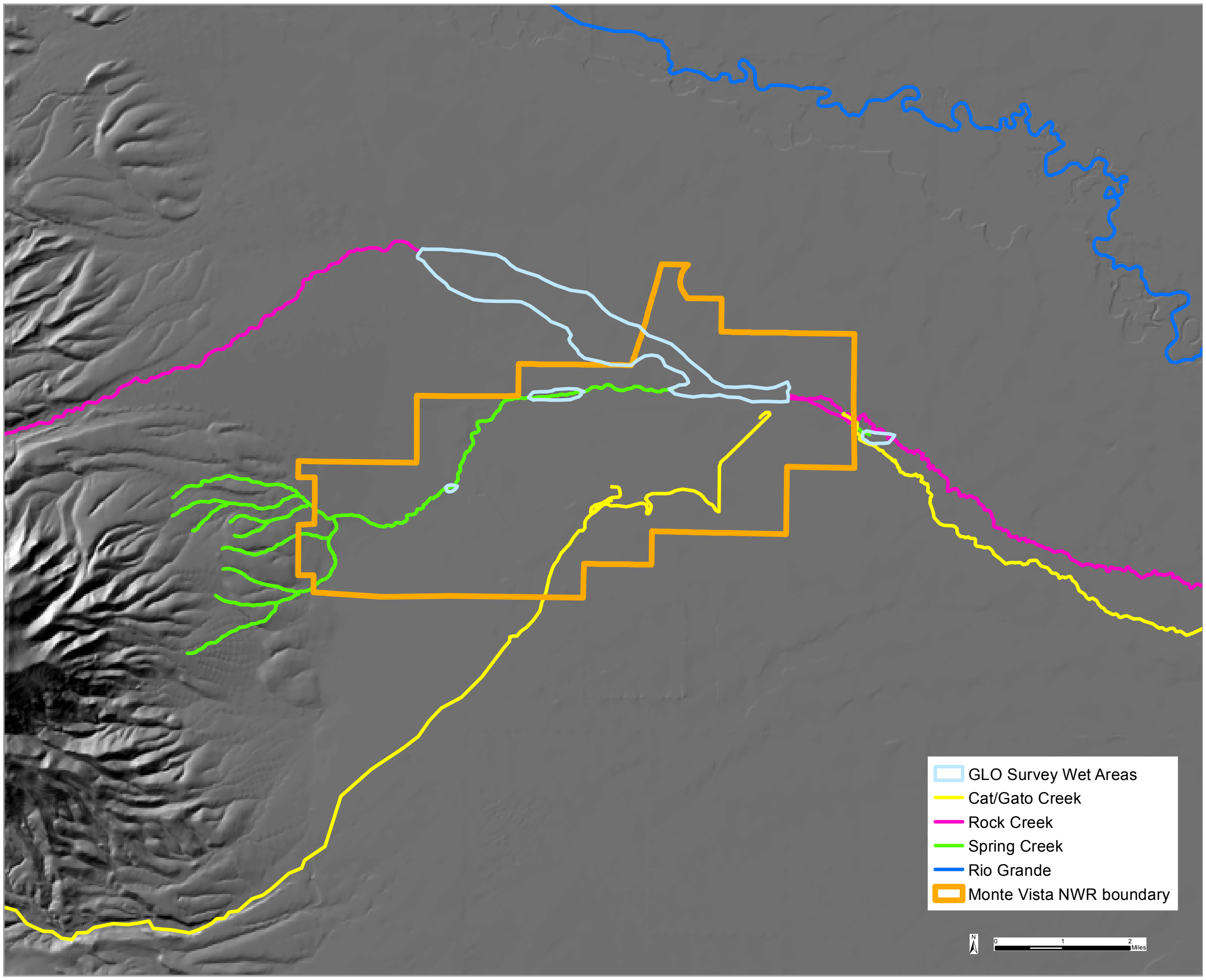


Figure 6. Location of major creeks flowing into and through Monte Vista National Wildlife Refuge.

locations of periodically flooded "wetland meadow" sites on the edges and adjacent to recent and former floodplains and overflow sites along Rock, Spring, and Cat Creeks (Table 1). Collectively, areas that at some point received flooding and were historical wetlands are indicated by soils mapped to about 15% of the current refuge area.

TOPOGRAPHY

The SLV is a large high elevation mountain valley averaging about 7,500 feet above mean sea level (amsl). Light Detection and Ranging (LiDAR) elevation surveys for the SLV region were flown in fall 2011 and data recently have been processed to produce 1 m resolution digital elevation model (DEM) maps for the refuge area (Fig. 8). Elevations on the refuge slope from 7,732 feet on the west boundary to 7,586 feet on the east boundary (Fig. 8). The LiDAR-DEM maps clearly identify the San Juan Mountain foothill area on the refuge (shown in red to yellow shading) that sharply transitions onto the large alluvial fan surface that covers the remainder of the refuge. The former creek and channel areas of Spring, Rock, and Cat Creeks also are distinguishable as are more subtle topographic features such as relict scour and deposition surfaces related to their historic fluvial dynamics (Fig. 9). Land depressions, indicated by marked changes in topography within the larger alluvial fan, suggest possible wetland depressions that historically occurred along the creek drainage corridors, especially in the confluence area of Spring and Rock creeks. The General Land Office (GLO) maps prepared from 1875 to 1880 also show

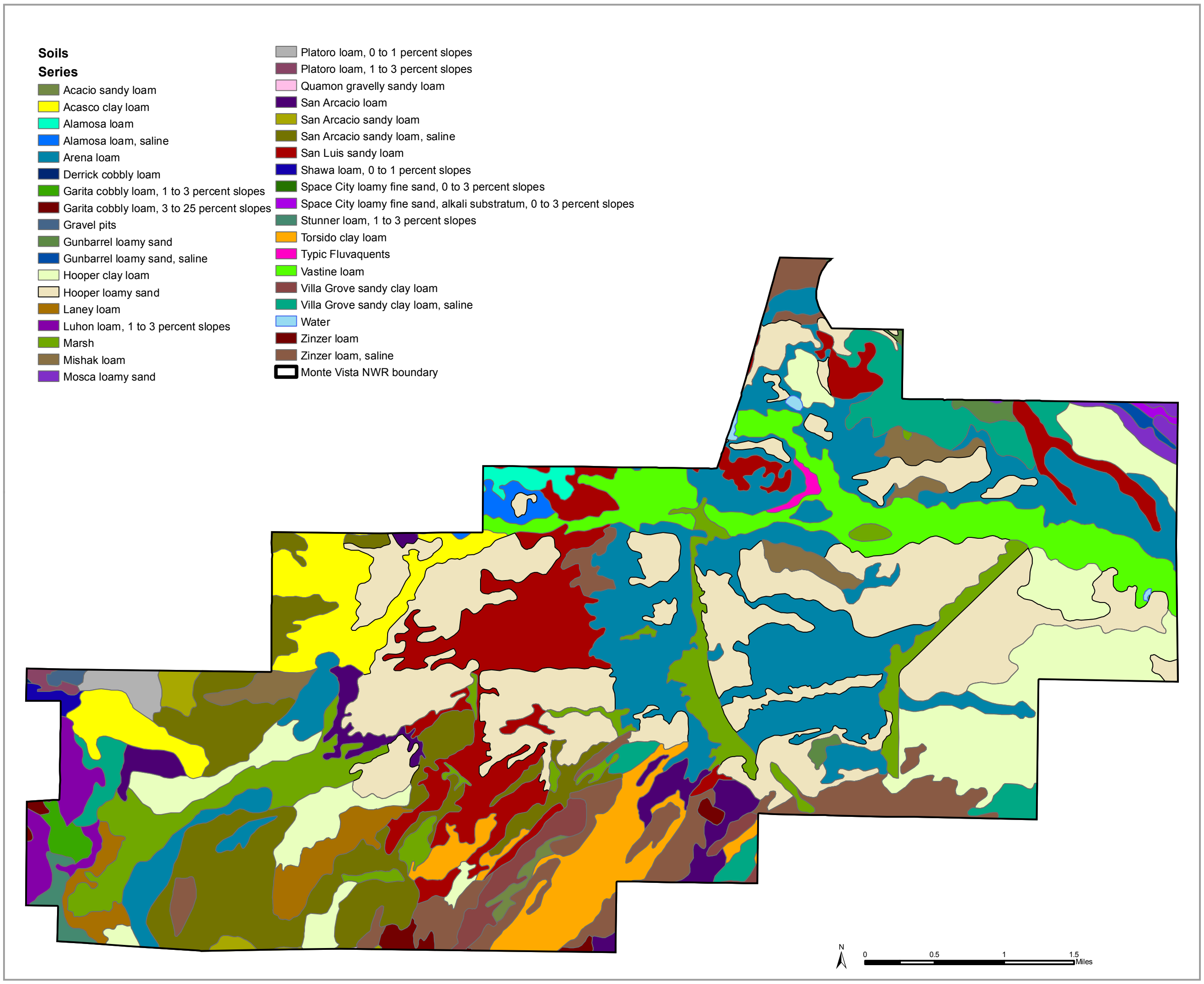


Figure 7. Soils on Monte Vista National Wildlife Refuge (from USDA SSURGO) datasets).

these wetland areas primarily along Rock Creek in the north-central part of the refuge (Fig. 10).

CLIMATE AND HYDROLOGY

The climate of the SLV is arid, with cold winters and moderate summers (Table 2). The Monte Vista area is in the pronounced rain shadow of the San Juan Mountains and receives about seven inches of precipitation per year (Table 3). About 60% of this precipitation occurs as rain in July and August. The source of summer moisture is the Gulfs of Mexico and California and is derived from monsoonal flow from the desert southwest. This monsoonal air moves north through Arizona and New Mexico into the SLV where no mountains obstruct the flow. Wide seasonal and annual variation in precipitation can occur in the SLV. Long-term precipitation data from Del Norte, Colorado west of Monte Vista NWR indicates annually dynamic patterns with frequent switches between dry (< 6 inches) and wet (> 12 inches) years (Fig. 11). Very dry periods in the long-term precipitation pattern for the period of record occurred in the early-1950s, the late-1970s, and the mid-2000s (Thomas 1963, Fig. 11). Generally, the long-term trend for total water year precipitation is increasing over time (Striffler 2012). Snow cover usually is sparse in the SLV and sometimes is completely lacking during much of the winter (BLM 1991). Mean annual temperature is 42° Fahrenheit at Del Norte. Temperatures of -20 to -30° Fahrenheit can be expected each year. The annual frost-free growing season averages about 90-100 days usually from late May through early September (SCS 1980), however wide annual variation occurs and July and August typically are the only consistent

Table 1. Soil types by acreage and percent (calculated from USDA SSURGO data).

Map Unit Name	Code	Acres	%
Hooper loamy sand	Ho	2,764.81	18.7%
Arena loam	Ar	2,296.01	15.6%
Hooper clay loam	Hp	1,375.78	9.3%
San Arcacio sandy loam, saline	Sc	1,225.74	8.3%
San Luis sandy loam	Sd	1,186.76	8.0%
Marsh	Ma	845.65	5.7%
Vastine loam	Va	839.25	5.7%
Zinzer loam, saline	Zr	762.62	5.2%
Acasco clay loam	Ac	587.28	4.0%
Torsido clay loam	To	517.34	3.5%
Villa Grove sandy clay loam, saline	Vh	490.81	3.3%
San Arcacio loam	Sa	319.07	2.2%
Laney loam	La	245.57	1.7%
Mishak loam	Mh	220.35	1.5%
Luhon loam, 1 to 3 percent slopes	LuB	176.00	1.2%
Villa Grove sandy clay loam, saline	Vg	155.34	1.1%
Platoro loam, 0 to 1 percent slopes	PaA	77.79	0.5%
San Arcacio sandy loam	Sb	67.75	0.5%
Mosca loamy sand	Ms	66.36	0.4%
Alamosa loam	Am	63.70	0.4%
Alamosa loam, saline	Ao	63.03	0.4%
Zinzer loam	Zn	59.07	0.4%
Gunbarrel loamy sand	Gs	56.05	0.4%
Stunner loam, 1 to 3 percent slopes	SrB	55.46	0.4%
Garita cobbly loam, 1 to 3 percent slopes	GaB	52.98	0.4%
Acacio sandy loam	Aa	34.90	0.2%
Shawa loam, 0 to 1 percent slopes	SmA	28.25	0.2%
Platoro loam, 1 to 3 percent slopes	PaB	22.05	0.1%
Typic Fluvaquents	Tt	20.87	0.1%
Gunbarrel loamy sand, saline	Gu	20.76	0.1%
Gravel pits	Gp	17.59	0.1%
Water	W	12.46	0.1%
Space City loamy fine sand, alkali substratum, 0 to 3 percent slopes	SpB	12.44	0.1%
Garita cobbly loam, 3 to 25 percent slopes	GaE	11.50	0.1%
Derrick cobbly loam	De	0.77	0.0%
Quamon gravelly sandy loam	Qa	0.54	0.0%
Space City loamy fine sand, 0 to 3 percent slopes	Snb	0.24	0.0%
Total		14,752.94	

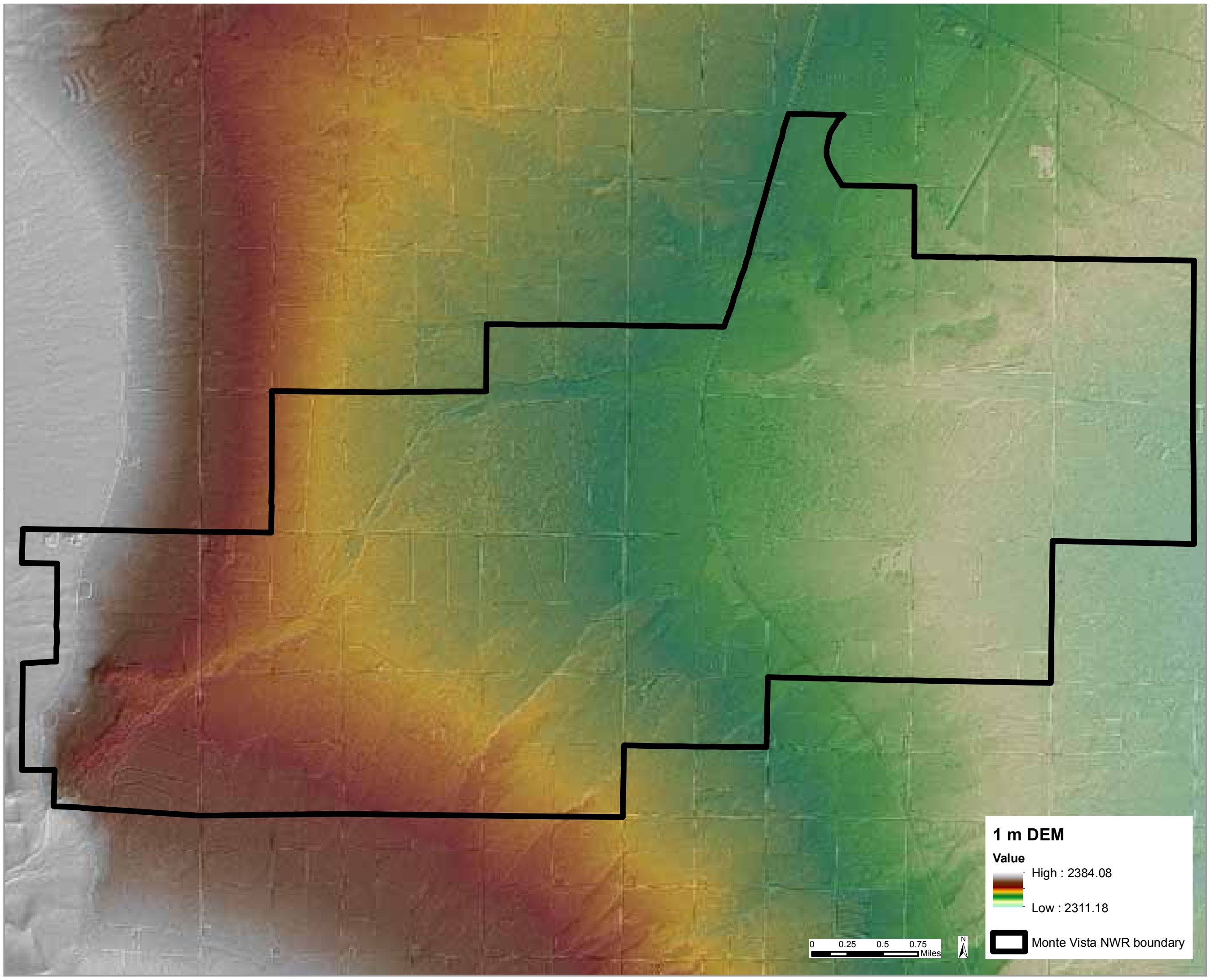


Figure 8. One meter DEM LiDAR elevations for Monte Vista National Wildlife Refuge.

completely frost-free months. Evapotranspiration (ET) rates at Monte Vista NWR typically are 45-50 inches per year (Leonard and Watts 1989, Ellis et al. 1993). A precipitation deficit (where potential ET exceeds precipitation) occurs every month of the year with the largest deficits occurring in June (Leonard and Watts 1989). Prevailing winds usually are from the south-southwest and light, although wind speeds of 40+ miles per hour can commonly occur in spring and early summer.

Historically, Monte Vista NWR received annual inputs of surface water primarily from limited onsite precipitation during summer and surface water drainage from Rock, Spring, and Cat Creeks (Striffler 2012). Rock Creek historically was fed primarily by snowmelt and rain runoff from the San Juan Mountains; it also received some ground-water discharge from local groundwater seeps and "springs." Sub-surface drainage likely contributed to the baseflow of the creek, but historical information on the seasonal and annual discharge dynamics of Rock Creek is limited. The original Rock and Spring Creek channels have been highly modified and currently carries water diverted from the Monte Vista Canal and irrigation return flow from hay fields irrigated from the Rio Grande Piedra Valley Ditch. Spring Creek, as its name implies, historically was primarily fed by a relatively large groundwater spring discharge "head" located in the southwest corner of Management Unit 19 (Figs. 6,12). Spring Creek also had small headwater drainages in the eastern San Juan Mountain foothills that coalesced at the Spring Creek discharge head point. This spring formerly produced groundwater discharges of up to 18 cubic feet/second (cfs) and water flowed east about 5.8 miles through the refuge and even-

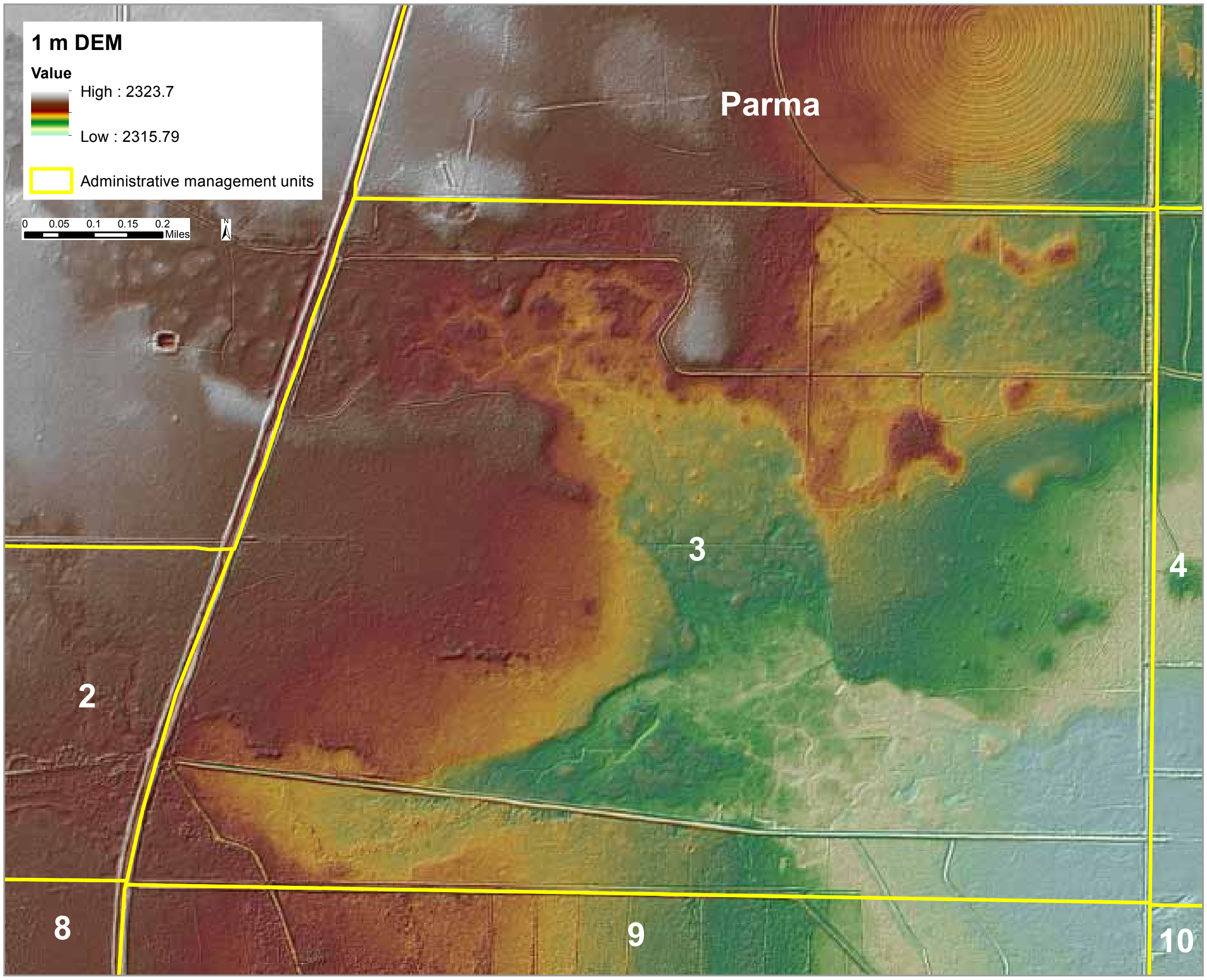


Figure 9. One meter DEM LiDAR elevations of Unit 3 in Monte Vista NWR.

tually joined Rock Creek along the eastern boundary of Unit 4 (Striffler 2012).

Early-1900s maps of the SLV (Siebenthal 1906, Clason 1910) indicate the presence of a small creek that originated in the San Juan Mountains south of Spring Creek that flowed northeast and ended in sections 9 and 10 of the southeast part of Monte Vista NWR (Fig. 6). The precise point where this creek ceased flowing is unknown. Apparently a ditch was dug in the late-1800s or early-1900s to irrigate meadow areas off of the creek; this ditch was subsequently ruled out of compliance and water rights were moved upstream by Terrace Reservoir. This ditch system off of the creek no longer exists, but its historic presence suggests some extension of creek flow or effect beyond the current Empire Canal. Siebenthal's map named this creek "Gato Creek", while Clason named the creek "Cat Creek." "Gato" is Spanish for the word "cat" and it is assumed the two differently named creeks are the same. Information on construction of a military wagon road from Alamosa to Pagosa Springs stated: "From Alamosa due west across the San Luis Valley, a natural road leads to Cat Creek, or El Rito de Gato, eighteen miles: and up the canyon of this creek and over a low divide, ..." (Denver Daily Tribune 1878). From this account, it appears that "Cat" or "Gato" were both used as the name for this drainage. More recent USGS quadrangle map shows a "Cat Creek" as a parallel creek south of Rock Creek that joins Rock Creek in section 18 just southwest of the town of Alamosa. Neither Gato nor Cat Creek is identified on Monte Vista NWR in the 1800s GLO map (Fig. 10), but is noted as exiting the foothills southwest of the refuge. Regardless of name, the Gato/Cat Creek drainage apparently did flow into the south end of the current Monte Vista NWR, at least in the late-

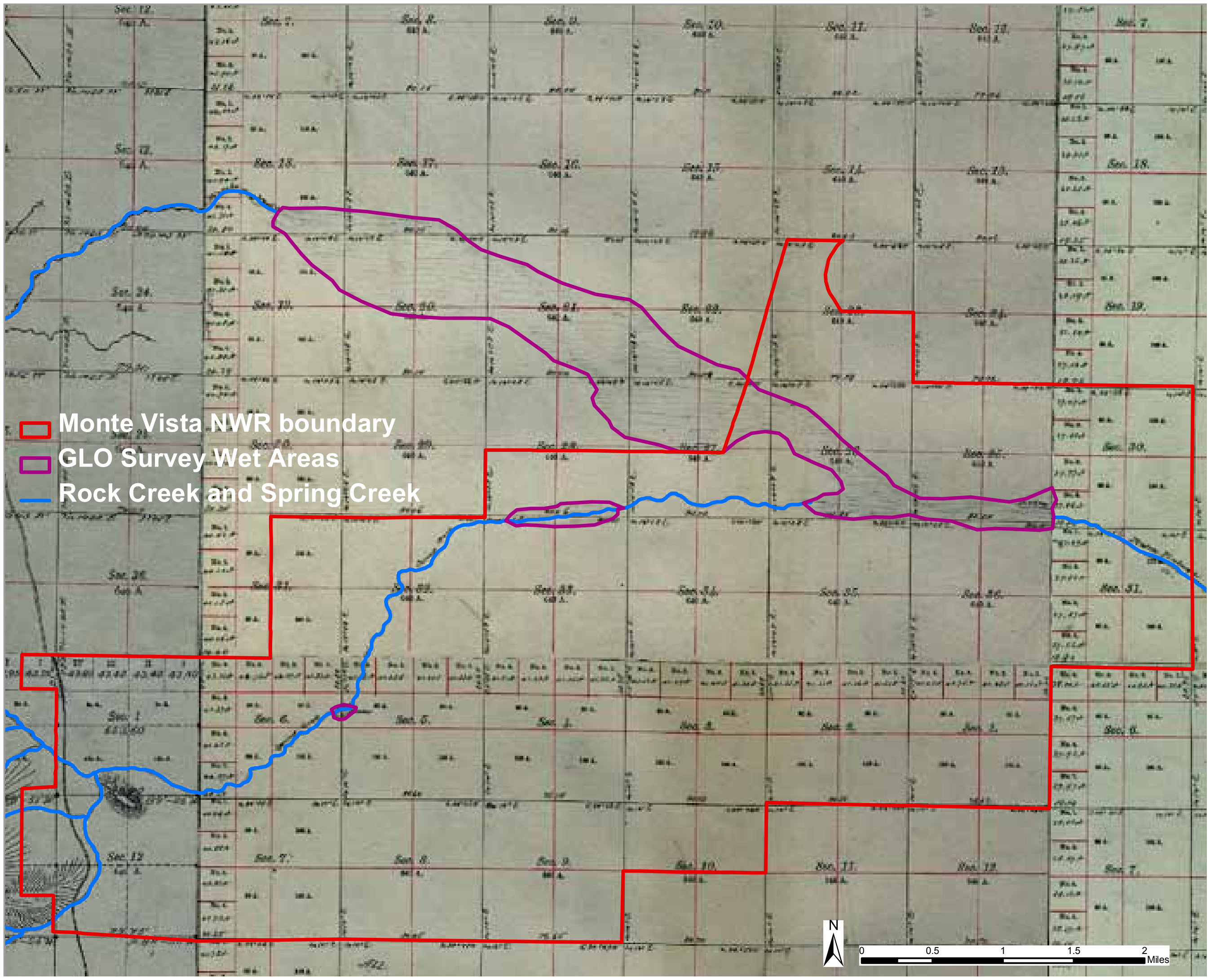


Figure 10. General Land Office map of the Monte Vista National Wildlife Refuge region.

1800s to early-1900s. The former existence of a creek at this location on Monte Vista NWR is corroborated in part by the presence of Acasco and Torsido clay loam "wetland type" soils in this area (SCS 1980, Fig. 7). Given the sporadic documentation of this creek in various reports, maps, surveys, and aerial photographs, it seems reasonable to assume that Cat Creek was an intermittent stream that contained surface water flow during peak seasonal runoff periods and during wetter years. This "intermittent" hypothesis might account for the disappearance of the creek in the southern portion of the refuge and its re-emergence south of Rock Creek to the east. Further, its absence from the GLO and other documents in the Monte Vista NWR area may reflect drought or dry seasons when the GLO survey occurred.

The modern floodplain of the Rio Grande does not extend into Monte Vista NWR, but historical high river flows may have occasionally slowed the drainage from the Spring-Rock Creek system and caused a small amount of backwater flooding up these creeks (Follansbee et al. 1915). However, no reference was located that indicates wide-spread flooding occurred historically on Monte Vista NWR lands from either overbank creek flows or backwater flooding from the Rio Grande (Striffler 2012). Unfortunately, no long-term gauge data are available for either Spring or Rock Creek. The existing gauge data on Rock Creek covers a 20 year period from 1935 to 1955 and indicates that peak flows typically occur in May, which contributes to the peak in Rio Grande flows in June (USGS monthly stream gauge data). Long-term precipitation data from the broader SLV region suggests an alternating wet-dry regional precipitation and river flow pattern. We assume that annual long-term variation in creek flows followed

Table 2. Temperature data from 1971-2000 at Alamosa Bergman Field, CO (from National Climatic Data Center, www.ncdc.noaa.gov).

Temperature (°F)																					
Mean (1)				**Extremes**											**Degree Days (1) Base Temp 65**		**Mean Number of Days (3)**					
Month	**Daily Max**	**Daily Min**	**Mean**	**Highest Daily(2)**	**Year**	**Day**	**Highest Month(1) Mean**	**Year**	**Lowest Daily(2)**	**Year**	**Day**	**Lowest Month(1) Mean**	**Year**	**Heating**	**Cooling**	**Max >= 100**	**Max >= 90**	**Max >= 50**	**Max <= 32**	**Min <= 32**	**Min <= 0**
Jan	33.1	-3.7	14.7	62	1971	20	25.6	1999	-41	1963	13	.6	1984	1551	0	.0	.0	2.0	13.7	31.0	18.5
Feb	40.2	4.7	22.5	66	1986	25	33.3	1995	-30+	1989	7	9.4	1979	1189	0	.0	.0	6.2	5.9	28.2	9.1
Mar	49.6	15.8	32.7	73+	1989	10	37.3	1999	-20	1964	4	26.1	1984	985	0	.0	.0	16.4	.8	30.6	1.0
Apr	58.7	22.8	40.8	80	1989	20	47.0	1992	-6	1973	8	35.5	1983	719	0	.0	.0	24.7	.1	27.0	.1
May	68.3	32.4	50.4	89	2000	29	55.2	1996	11	1967	1	46.2	1983	451	0	.0	.0	30.2	.0	13.7	.0
Jun	78.4	40.4	59.4	95	1994	26	62.4	1981	24	1990	2	56.0	1983	169	7	.0	.5	30.0	.0	1.8	.0
Jul	81.7	46.4	64.1	96	1989	5	66.7	1980	30	1997	2	62.1	1995	47	27	.0	.8	31.0	.0	@	.0
Aug	78.9	45.2	62.1	90	1977	7	64.7	1995	29	1964	21	58.3	1974	91	10	.0	@	31.0	.0	.1	.0
Sep	72.5	36.5	54.5	87+	1990	13	57.9+	1998	15+	1999	29	51.5	1985	302	0	.0	.0	29.9	.0	7.2	.0
Oct	61.7	23.9	42.8	81	1979	7	45.9	1992	-9	1991	31	39.1	1976	675	0	.0	.0	27.5	.3	27.0	.1
Nov	45.7	11.1	28.4	71+	1980	10	34.1	1998	-30	1952	27	17.8	1972	1082	0	.0	.0	12.2	3.9	29.5	4.3
Dec	34.8	-.7	17.1	61	1958	8	27.4	1980	-42+	1978	8	4.9	1991	1475	0	.0	.0	2.2	11.5	31.0	15.6
Ann	58.6	22.9	40.8	96	Jul 1989	5	66.7	Jul 1980	-42+	Dec 1978	8	.6	Jan 1984	8736	44	.0	1.3	243.3	36.2	227.1	48.7

trends in annual precipitation amounts (see Fig. 11 and discussion in McGowan and Plazak 1996).

The thick basin-fill deposits of interbedded clay, silt, gravel, and volcanic rock form two main aquifers (confined and unconfined) in the SLV (Burroughs 1981, Wilkins 1998, Hanna and Harmon 1989). The two aquifers are separated by a confining layer of discontinuous clay beds and volcanic rocks (Fig. 13, Emery et al. 1973). The unconfined alluvial aquifer underlies Monte Vista NWR to a depth of about 40+ feet. On the west side of the SLV the majority of the unconfined aquifer is comprised of Lower Alamosa and the Los Pinos geological strata formations. Hydraulic conductivity of the unconfined aquifer can range from 35 to 235 feet/day, with the highest values near the western edge of the SLV (Hanna and Harmon 1989). Natural recharge to the unconfined aquifer occurs from infiltration of local precipitation along the margins of the SLV, infiltration of surface water from natural stream channels (i.e., Rock and Spring Creeks), inflow of groundwater from the adjacent San Juan Mountains, and upward leakage of groundwater through the confining bed (Powell 1958, McGowan and Plazak 1996). Recharge of the unconfined aquifer is strongly affected by annual changes in runoff from the surrounding mountains, which is a function of annual snowpack and melting dynamics. Discharge from the unconfined aquifer includes ET, groundwater discharge to streams and creeks, and some groundwater flow to the south.

The confined aquifer occurs below the unconfined alluvial aquifer and consists of an active and passive zone (Fig. 13). At the periphery of the SLV, the unconfined and active confined aquifers are directly connected hydraulically. Recharge to the active confined aquifer takes place, in part, through the unconfined aquifer at these locations. The active confined aquifer is up to 4,000 feet below the land surface. Recharge to the confined aquifer occurs along the margins of the SLV from infiltration of precipitation, infiltration of surface water, and inflow of groundwater from the adjacent San Juan Mountains. Discharge from the confined aquifer occurs as groundwater flow to the south and upward leakage through the confining bed. A generalized schematic of hydrologic flow in the San Luis Valley (including current modifications and management) is provided in Fig. 14.

PLANT AND ANIMAL COMMUNITIES

Historically, an upland grassland or "under-shrub-grassland" xeric community dominated the San Juan Mountain foothills on the far west side of the refuge. A salt desert shrub community dominated the large Rio Grande alluvial fan that extended east from the San Juan Mountains to the Rio Grande floodplain and SLV floor (Hayden 1873; Hanson 1929; Ramaley 1929, 1942; Har-

Table 3. Precipitation data from 1971-2000 at Alamosa Bergman Field, CO (from National Climatic Data Center, www.ncdc.noaa.gov).

Precipitation (inches)																								
	Precipitation Totals									Mean Number of Days (3)				Precipitation Probabilities (1) Probability that the monthly/annual precipitation will be equal to or less than the indicated amount										
	Means/ Medians(1)		Extremes							Daily Precipitation				Monthly/Annual Precipitation vs Probability Levels These values were determined from the incomplete gamma distribution										
Month	Mean	Med-ian	Highest Daily(2)	Year	Day	Highest Monthly(1)	Year	Lowest Monthly(1)	Year	>= 0.01	>= 0.10	>= 0.50	>= 1.00	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
Jan	.25	.23	.33+	1974	1	.75	1979	.00+	1998	3.8	.9	.0	.0	.00	.03	.08	.12	.16	.21	.26	.32	.40	.53	.66
Feb	.21	.21	.88	1963	10	.77	1997	.00	1999	3.8	.7	.0	.0	.01	.03	.06	.09	.12	.16	.21	.26	.34	.46	.59
Mar	.46	.38	1.15	1992	4	1.62	1992	.03	1971	5.4	1.5	.1	@	.05	.09	.15	.22	.29	.36	.45	.56	.71	.96	1.20
Apr	.54	.42	1.22	1952	20	1.72	1990	.00	1972	5.1	1.6	.2	@	.02	.07	.15	.22	.31	.40	.52	.66	.85	1.17	1.49
May	.70	.70	.86	1967	26	1.85	1973	.01+	1998	6.1	2.3	.3	.0	.03	.06	.14	.23	.34	.47	.63	.84	1.13	1.63	2.14
Jun	.59	.58	1.02	1969	16	1.26	1995	.00	1980	5.4	1.9	.1	.0	.05	.11	.20	.29	.38	.48	.59	.73	.92	1.22	1.51
Jul	.94	.77	1.56	1971	18	2.59	1971	.02	1994	8.5	2.6	.2	@	.10	.17	.30	.43	.57	.73	.92	1.15	1.47	2.00	2.52
Aug	1.19	.98	1.31	1993	27	5.40	1993	.21	1980	10.1	3.6	.4	.1	.25	.36	.54	.70	.85	1.02	1.22	1.45	1.75	2.23	2.69
Sep	.89	.81	1.77	1959	30	1.85	1982	.19	1978	6.4	2.8	.3	.0	.21	.30	.43	.54	.66	.78	.92	1.08	1.29	1.63	1.95
Oct	.67	.52	.89	1969	11	2.16	1972	.00+	1995	4.8	2.1	.3	.0	.00	.07	.18	.29	.40	.52	.66	.83	1.07	1.46	1.83
Nov	.48	.44	.71	1981	7	1.23	1991	.00+	1999	4.4	1.5	.1	.0	.00	.04	.12	.20	.28	.37	.47	.60	.77	1.06	1.34
Dec	.33	.19	.91	1964	3	.99	1983	.00+	1996	4.0	1.1	.1	.0	.00	.02	.06	.11	.17	.23	.31	.41	.54	.78	1.01
Ann	7.25	7.18	1.77	Sep 1959	30	5.40	Aug 1993	.00+	Nov 1999	67.8	22.6	2.1	.1	4.80	5.27	5.86	6.32	6.73	7.13	7.55	8.01	8.58	9.40	10.12

Snow (inches)																							
Snow Totals															Mean Number of Days (1)								
Means/Medians (1)					Extremes (2)										Snow Fall >= Thresholds					Snow Depth >= Thresholds			
Month	Snow Fall Mean	Snow Fall Median	Snow Depth Mean	Snow Depth Median	Highest Daily Snow Fall	Year	Day	Highest Monthly Snow Fall	Year	Highest Daily Snow Depth	Year	Day	Highest Monthly Mean Snow Depth	Year	0.1	1.0	3.0	5.0	10.0	1	3	5	10
Jan	4.6	3.3	2	1	6.4	1974	1	17.8	1974	10+	1992	31	10	1992	4.1	1.4	.4	.2	.0	16.2	8.6	6.0	.9
Feb	2.7	2.5	1	1	3.5	1971	3	7.0	1987	10+	1992	20	9	1992	3.6	1.1	.1	.0	.0	9.0	4.6	3.1	.4
Mar	5.9	4.1	#	1	12.0	1992	4	29.2	1973	11	1992	5	3	1992	4.9	2.0	.4	.2	.1	3.6	1.2	.6	@
Apr	3.7	3.2	#	0	9.0	1990	30	9.2	1990	5+	1987	13	#	2000	2.7	1.0	.4	.2	.0	.9	.2	.1	.0
May	2.1	.1	#	0	8.4	1973	6	13.5	1978	4	1978	5	#	2000	1.3	.7	.2	.1	.0	.3	@	.0	.0
Jun	.0	.0	#	0	.2	1983	13	.2	1983	#	1990	9	#	1999	.0	.0	.0	.0	.0	.0	.0	.0	.0
Jul	.0	.0	#	0	.0	0	0	.0	0	#+	1990	26	#	1997	.0	.0	.0	.0	.0	.0	.0	.0	.0
Aug	.0	.0	0	0	.0	0	0	.0	0	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Sep	.1	.0	0	0	1.2	1971	18	1.2	1971	#	1973	26	0	0	.1	.1	.0	.0	.0	.0	.0	.0	.0
Oct	3.0	.5	#	0	13.1	1991	30	15.1	1991	12	1991	31	1	1991	1.3	.7	.3	.2	.1	.8	.2	.1	@
Nov	4.7	3.7	1	0	8.0	1985	14	19.8	1972	12	1972	1	4	1972	3.6	1.4	.5	.1	.0	5.4	2.6	.9	@
Dec	5.1	4.9	1	1	9.6	1978	6	12.1	1978	10+	1991	27	6	1991	4.3	1.6	.5	.2	.0	12.6	6.8	2.6	.2
Ann	31.9	22.3	N/A	N/A	13.1	Oct 1991	30	29.2	Mar 1973	12+	Oct 1991	31	10	Jan 1992	25.9	10.0	2.8	1.2	.2	48.8	24.2	13.4	1.5

rington 1954). Relatively narrow creek channels and their floodplains bisected the alluvial fan and contained narrow bands of wetland habitat. The GLO maps and survey notes indicate that most wetlands occurred along Rock Creek and at the junction of Spring and Rock Creeks in the northern part of Monte Vista NWR (Fig. 10). As previously mentioned, Cat Creek flowed intermittently into the south part of the refuge (Fig. 6) where it apparently dissipated and created a wet meadow/ seasonal wetland area.

Vegetation in the SLV historically was highly influenced by the relatively low, but intense, amounts of late summer rainfall that usually occurred as thundershowers (Ramaley 1929, 1942). Most annual plants in the SLV germinate and grow, and most perennial plants flower, during the late summer (Carsey et al. 2003). Generally, little new plant growth occurs in the SLV before June because freezing weather continues through most of May and light frosts are likely to occur into early June. The surface soils in the SLV, outside of creek-riparian areas, usually are

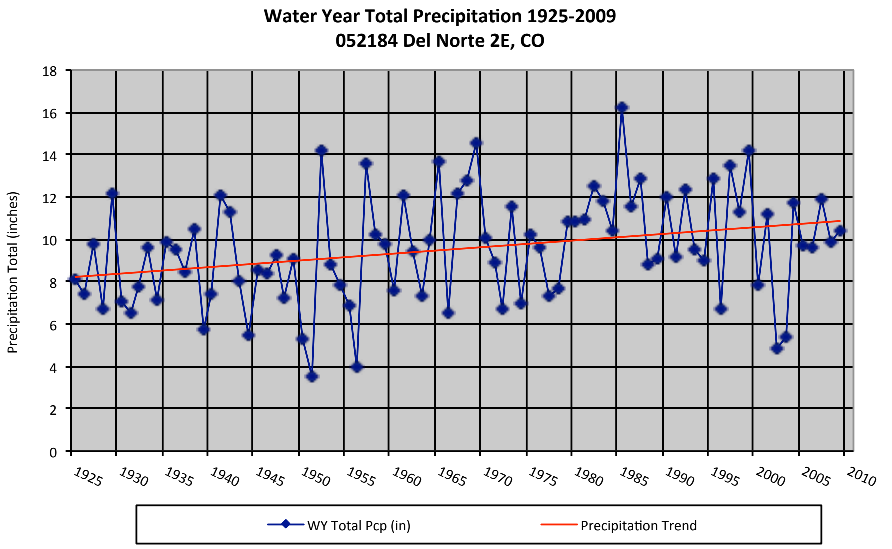


Figure 11. Total water year precipitation (inches) for Del Norte, CO, 1925-2009 (from Striffler 2012).

dry until early summer because little precipitation occurs in winter and early spring. Even if soils are not dry in spring the cold temperatures prevent plant germination until June.

The extensive salt desert shrub community at Monte Vista NWR and throughout the floor of the SLV was present on mixed alluvium soils and contained primarily greasewood (*Sarcobatus vermiculatus*), rubber rabbitbrush (*Ericameria nauseosa*), shadscale (*Atriplex canescens*), alkali sacaton (*Sporobolus airoides*), and saltgrass (*Distichlis spicata*) (Ramaley 1942). Scattered sagebrush (*Artemsia tridentata*) was present in transition areas between salt desert shrub and foothill "undershrub" grassland habitats. Soils in salt desert shrub areas typically are poorly drained and historically groundwater tables were relatively close to the surface (Cronquist et al. 1977). Even slight differences in elevation of a few inches can alter drainage and can cause ephemeral or seasonal surface water "ponding", which creates significant variation in soil salinity and consequently heterogeneity in plant species occurrence. For example, excess alkali occurs when water tables are close to the ground surface, especially in shallow depressional "pool" areas; these small depression sites typically contain saltgrass, chairmaker's rush (*Scirpus pungens)*, foxtail barley (*Hordeum jubatum)*, alkali muhly (*Mulhenbergia asperifolia*), *a*nd several other sedge and rush species (Ramaley 1942). Where alkali is extremely high, "chico slick spots" that consist of barren salt flats are typical within scattered greasewood clumps. Generally more saline subhabitats within the salt desert shrub area can be determined by salinity of soils (SCS 1980, Fig. 7). Tussocks of alkali sacaton occur between shrubs, but ground cover generally is sparse with substantial amounts of bare ground present. In a few areas, short wind-formed ridges are present in salt desert shrub communities and they typically support rabbitbrush where greater aeration of roots can occur. Many herbaceous species are present in the salt desert shrub habitats, including scattered grasses, sedges, rushes, and legumes with individual species presence reflecting soil aeration, seasonal ponding of water in small depressions, and depth to groundwater (e.g., Ramaley 1942).

The outer margin of salt desert shrub habitats changes from a greasewood dominated plant assemblage to an "undershrub-grama grass" community in valley-margin foothill areas (Ramaley 1942). These sites, which also have been called "limy bench" or "mountain outwash" areas (SCS 1980) are dominated by blue grama (*Bouteloua gracilis*), winterfat (*Eurotia lanata*), rabbitbrush, Indian ricegrass (*Acnatherum hymenoides*), and snakeweed (*Gutierrezia sarothrae*). Yucca (*Yucca glauca)* sometimes is present in these foothill areas as is buckwheat (*Eriogonum* spp.). Processes such as soil creep and overland flow associated with the formation of alluvial fans where the Rio Grande and small creeks exited the San Juan Mountains into the SLV distributed sediments differentially across the fan (SCS 1980, Burroughs 1981). This transfer of material influences soil structure, chemistry, infiltration, and percolation on the fans and adjacent foothill slopes. Shrubland community composition and structure varies based on these changes and also helps further change soil characteristics existing immediately below an individual shrub and the adjacent bare soil (Bedford and Small 2007). Soils in upland foothill sites are characterized by Luhon-Garita-Travelers association coarse-texture types and the groundwater table is much deeper than in the SLV floor areas (SCS 1980). Snakeweed and rabbitbrush usually are present on higher, drier sites, whereas sagebrush occupied areas with finer-texture soils and in shallow depressions (Ramaley 1942).

Mountain sage (*Artemisia frigida*) can occur in alluvial washes and ground disturbed by rodents or grazing animals.

The relatively narrow historical creek corridors at Monte Vista NWR include active and relict channels and associated small floodplains of Rock, Spring, and Cat Creeks. Remnant floodplain and abandoned creek channel depressions are present in some locations and contain wetlands with diverse sedges, rushes, alkali muhly, and some small pockets of cattail and softstem bulrush (Ramaley 1929, 1942; Carsey et al. 2003, Figs. 6, 10). GLO survey maps were prepared for the "flat" portions of the refuge in 1875 and the foothill areas were mapped by 1880. These GLO maps indicate that wetland areas on and near Monte Vista NWR were limited to relatively narrow corridors along the creeks, especially the northern Rock Creek drainage, along Spring Creek, and the Cat Creek channel (Figs. 6,10). Wetlands and sloughs in the SLV and at Monte Vista NWR, historically were seasonally flooded in late spring and early summer from snowmelt, spring rainfall, creek overflows, and groundwater discharge, with some wetlands holding water into July (Ramaley 1929, 1942; Rees 1939, Cooper and Severn 1992). Wetland sites have fine-grained Torrifluvent-Torsido-Alamosa soil associations that are relatively impermeable and lose little water from seepage; most surface water loss occurs from the high ET rates during summer (SCS 1980). The Vastine soil type is the most common wetland associated soil on Monte Vista NWR (Table 1, Fig. 7). Little evidence exists that deeper, more permanently flooded, wetland depressions historically occurred at Monte Vista NWR. However, occasional prolonged surface flooding may have occurred in a few areas along Rock and Spring Creeks during wetter years. Hydrostatic pressure (absence of water flow through soil pores and the pressure on those pores) increases in the fall,

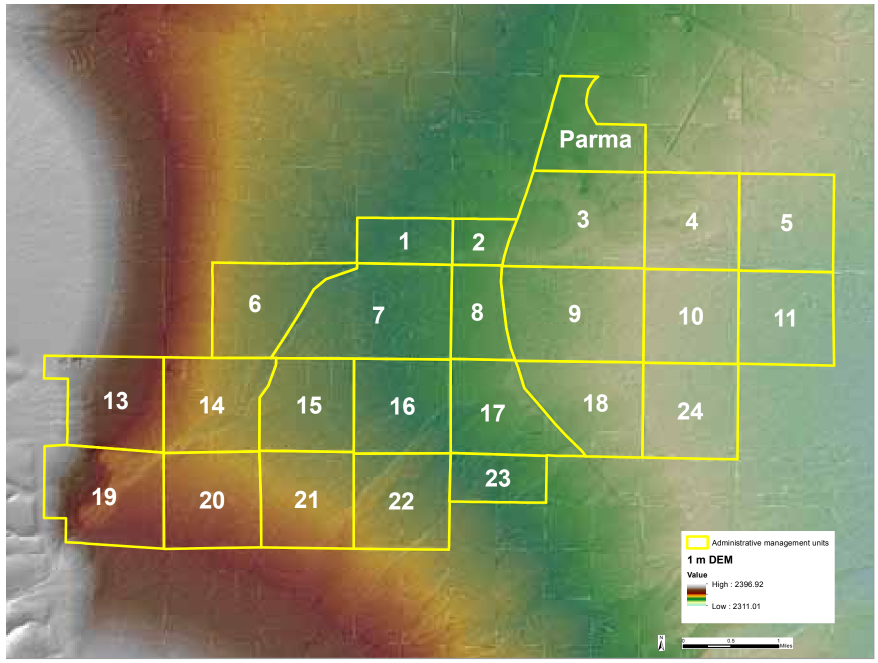


Figure 12. Administrative management units on Monte Vista National Wildlife Refuge.

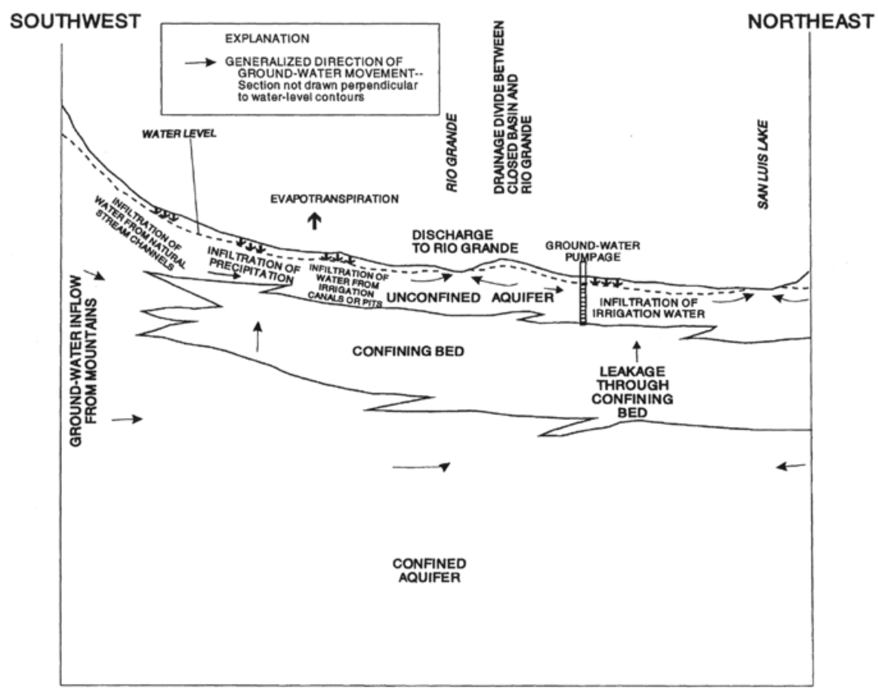


Figure 13. Schematic cross-section of groundwater movement in relation to the unconfined and confined aquifers in the San Luis Valley (modified from Hanna and Harmon 1989).

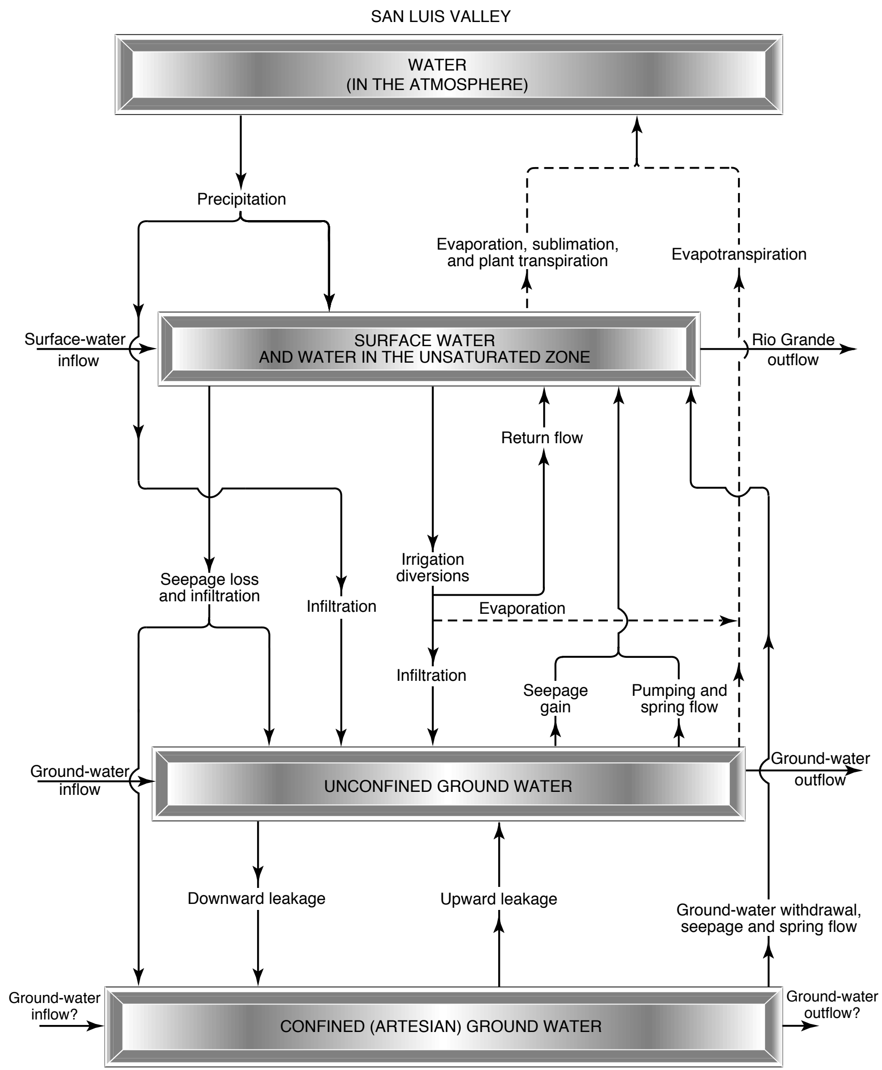


Figure 14. Generalized hydrological flow diagram of the San Luis Valley (modified from U.S. Bureau of Reclamation 1995 and Wilkins 1998).

which may have increased flows in some groundwater springs and created modest sheetflow that then froze creating sheet ice that may or may not have remained frozen until the following spring. The Spring Creek area may have historically supplied late fall water and potentially early spring water as the sheet ice melted (described in early refuge annual narratives).

Generally, it is believed that wetland habitats historically present in the SLV, and at Monte Vista NWR, probably contained concentric bands of vegetation (Ramaley 1942, Windell et al. 1986, Cooper and Severn 1992, Fig. 15) depending on size, depth, and frequency of inundation of the respective depressions. Natural wetland "ponds" in the SLV have: 1) a central deeper area with more prolonged flooding that includes some open water along with aquatic plants such as pondweeds (*Potamogeton* spp.) and tall and medium stature persistent emergent (PEM) plants such as cattail and softstem bulrush; 2) a "marsh" zone with abundant short stature emergent herbaceous plants that include perennial species such as sedges, spikerush, and rushes along with annual species such as dock (*Rumex* spp.), smartweed (*Polygonum* spp.), panic grass (*Panicum dichotimiflorum*), and millet (*Echnichloa* spp.); and 3) wet meadow zones (sometimes partitioned into "inner" and "outer" meadow communities) with many wet-type grasses, such as slimstem reedgrass (*Calamagrostis stricta*), sedges, and other herbaceous plants.

The edges of the historical Rock, Spring, and Cat Creek channels likely included a marginal wet meadow zone that contained diverse sedges, including many spikerushes, bulrush, *Carex* species, and *Juncus* species. Natural wet meadows also occurred just beyond the streambank zones. It is unknown if riparian trees such as willows or cottonwood historically occurred along Spring and Rock Creeks, but the relatively small seasonal discharge in these creeks, coupled with the arid conditions, likely limited trees to scattered clumps of sandbar willow perhaps in the area along the north Rock Creek drainage mapped by GLO surveys. Old literature on settlements in the Monte Vista NWR area does not mention any trees (e.g., Brown 1928).

A diverse assemblage of animal species historically was present in the various habitat types at Monte Vista NWR (Table 4). The majority of species were those adapted to salt desert shrub and creek-floodplain habitats (e.g., Laubhan and Gammonley 2000, D'Errico 2006) and included numerous upland birds, mammals, and reptiles. Wet meadow and wetland communities supported many waterbird, mammal, and amphibian/reptile species, especially during wet years when more flooding of meadows and wetland depressions occurred. The alternating wet vs. dry precipitation cycles in the SLV caused the availability of wetland habitat to be highly variable among years. Most waterbirds probably used the historic wetlands present on Monte Vista NWR mainly during migration, especially in spring; these included many species of waterfowl, shorebirds, and wading birds such as dabbling ducks, common snipe (*Gallinego gallinego*), American avocet (*Recurvirostra americana*), long-billed dowitcher (*Limnodromus scolopaceus*), various sandpipers (*Caldris* spp.), white-faced ibis (*Plegadis chihi*), pied-billed grebe (*Podilymbus podiceps*), sora (*Porzana carolina*), marsh wren (*Cistothorus palustris*), and yellow-headed blackbird (*Xanthocephalus xanthocephalus*). Grassland and upland shrub bird species such as Brewer's sparrow (*Spizella breweri*), sage sparrow (*Amphispiza belli*), sage thrasher (*Oreoscoptes mantanus*), and western meadowlark (*Sturnella neglecta*) probably utilized many of the grassland and shrub habitats in the refuge area. Mammals such as the desert cottontail (*Sylvilagus auduboni*), white tailed jackrabbit (*Lepus townsendii*), long tailed weasel (*Mustela frenata*), mule deer (*Odocoileus menionus*), and elk (*Cervus canadensis*) were common (as noted in Jacob Fowler's journal edited by Coues 1965). Amphibians and reptiles such as the western terrestrial garter snake (*Thamnophis elegans*), northern leopard frog (*Rana pipiens*), and various toads frequented wetland areas.

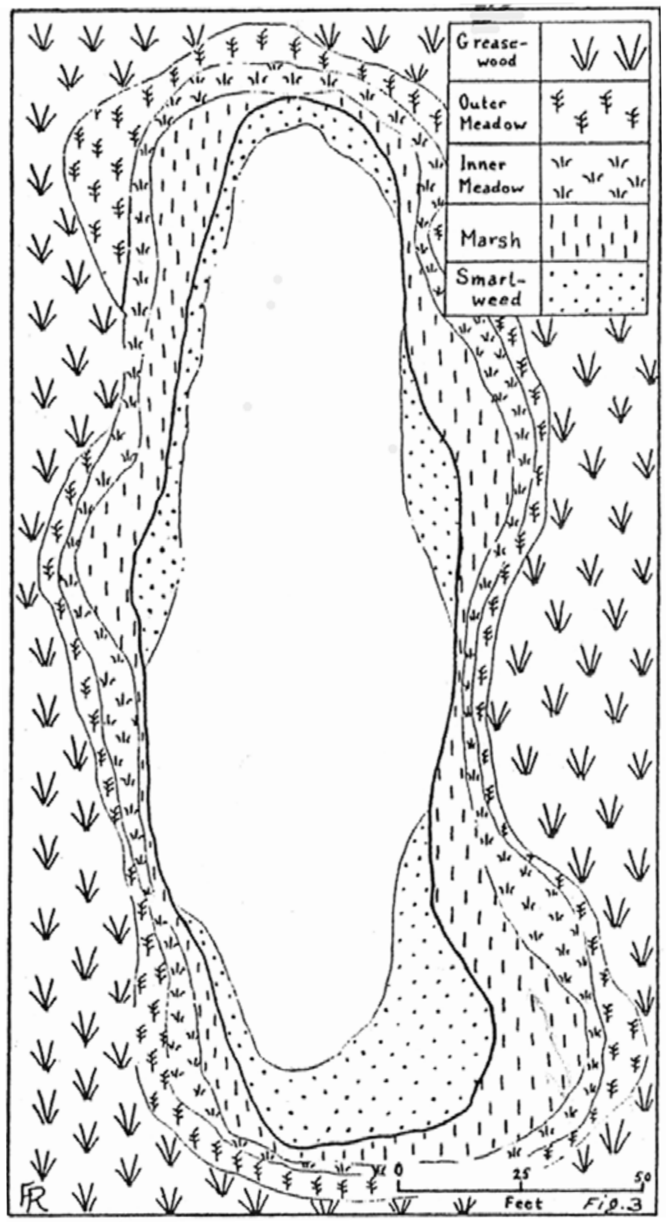


Figure 15. Vegetation associations around a typical semipermanently flooded wetland in the San Luis Valley (from Ramaley 1942).

HISTORICAL DISTRIBUTION AND EXTENT OF PLANT COMMUNITIES

An HGM matrix of the relationships between major plant communities and a combination of geomorphic surface, soil, topography, and hydrology attributes was developed (Table 5) to map potential distribution of historic communities on Monte Vista NWR (Fig. 16). Information used to develop this matrix included general plant communities described and mapped in the late 1800s by the GLO surveys, plant species associations described in published literature, older maps (Fig. 17), aerial photographs (Fig. 18), and state-of-the-art understanding of plant species relationships (i.e., botanical correlation) to geomorphology, soil, topography and elevation, hydrological regimes, and ecosystem disturbances (e.g., Carsey 2003, Robbins 1910, Summers and Smith 1927, Ramaley 1929, 1942, Hanson 1929, Harrington 1954, SCS 1980). These plant-abiotic correlations are the basis of plant biogeography and physiography (e.g., Barbour and Billings 1991, Bailey 1996). Obviously, the accuracy of predictions regarding type and distribution of communities depends on the quality and availability of geospatial data and plant-abiotic correlations (e.g., Allred and Mitchell 1955, Buck 1964) for the site and period of interest. For example, the precise delineation of historical small depressions within salt desert shrub areas that may have supported more meadow-type wetland vegetation is limited because the major topographic alterations that have occurred on and around the refuge from construction of the many roads, levees and dikes, ditches, canals, and water-control structures have destroyed former topographic features.

Table 4. Habitat types and utilization by select avian species on the Alamosa/Monte Vista NWR Complex.

Semiperm.(1'+)	Seasonal(<1')	Tall emergent	Short emergent	Saltgrass	Annuals	DNC	Riparian	Upland	Ag. Lands	Riverine
				Killdeer (ns.fo)						Killdeer (fo)
								Mountain plover(ns.fo)?		
	Black-necked stilt (ns.fo)			Black-necked stilt (ns.fo)						Black-necked stilt (fo)
	American avocet (ns.fo)		American avocet(fo)	American avocet (ns.fo)						American avocet(fo)
	Greater yellowlegs (fo)									Greater yellowlegs (fo)
	Lesser yellowlegs(fo)									Lesser yellowlegs(fo)
Solitary sandpiper (fo)	Spotted sandpiper(fo)									
	Long-billed curlew(lo,fo)		Long-billed curlew (fo)							
	Marbled godwit (fo)									
	Semi-palmated sandpiper (fo)									
	Western sandpiper(fo)									
	Least sandpiper(fo)									
	Baird's sandpiper(fo)									
	Pectoral Sandpiper(fo)									
	Stilt sandpiper(fo)									
	Long-billed dowitcher(fo)									
			Common snipe(ns,fo)							Common snipe(fo)
	Wilson's phalarope (fo)		Western phalarope (ns,fo)	Western phalarope (fo)						
	Red-necked phalarope (fo)									
Forster's tern (fo)	Forster's tern (fo)									
Least tern(fo)										
Black tern(fo)	Black tern(fo)	Black tern(fo)								
			Great Horned owl (fo)			Great Horned owl (fo)	Great Horned owl (ns)			
								Burrowing owl (ns,fo)		
			Short-eared owl(ns,fo)			Short-eared owl(ns,fo)				
							Willow flycatcher(ns,fo)			
		Marsh wren(ns,fo)								
								Sage thrasher (ns,fo)		
								Loggerhead shrike (ns,fo)		
							Yellow warbler (ns,fs)			

Table 4, Cont'd.

Semiperm.(1'+)	Seasonal(<1')	Tall emergent	Short emergent	Saltgrass	Annuals	DNC	Riparian	Upland	Ag. Lands	Riverine
							Yellow-breasted chat (ns,fo)?			
							Blue grosbeak (ns,fo)?			
							Indigo bunting (ns,fo)			
								Brewer's sparrow (ns,fo)		
			Vesper sparrow (ns,fo)	Vesper sparrow (ns,fo)						
			Savannah sparrow (ns,for)	Savannah sparrow (ns,fo)						
			Western meadowlark (ns,fo)							
		Yellowheaded blackbird (ns,fo)								
		Brewer's blackbird (ns,fo)								
							Bullock's oriole (ns,fo)			
Eared grebe (ns,fo)										
Pie-billed grebe (ns,fo)										
Western grebe (fo)										
American White pelican (fo)										
		Am.Bittern (ns)	Am.Bittern (fo)							
	Snowy egret (fo)	Snowy egret (ns)								Snowy egret (n
	Cattle egret (ns)	Cattle egret (fo)								
	Black-crowned night. heron (ns)									Black-crowned night heron (fo)
	White-faced ibis (fo)	White-faced ibis(ns)	White-faced ibis(fo)	White-faced ibis(fo)						
Canada geese(mo)		Canada geese(ns)	Canada geese(ns)						Canada geese (fo)	Canada geese (ro)
	Mallard(fo)	Mallard(br,ns)	Mallard(ns,fo)	Mallard(fo)	Mallard(fo)	Mallard(ns)		Mallard(ns)	Mallard(fo)	Mallard(ro)
Gadwall(fo)		Gadwall(br)	Gadwall(ns)		Gadwall(fo)	Gadwall(ns)		Gadwall(ns)		Gadwall(ro)
		Pintail(br)	Pintail(ns)	Pintail(fo)	Pintail(fo)	Pintail(ns)			Pintail(fo)	Pintail(ro)
			Green-wing teal(ns,br)		Green-wing teal(fo)				Green-wing teal(fo)	Green-wing teal(ro)
	Blue-wing cinnamon teal(fo)		Blue-wing cinnamon teal(ns,br)	Blue-wing cinnamon teal(fo)	Blue-wing cinnamon teal(fo)					Blue-wing cinnamon teal(ro)
	Shoveler(fo)		Shoveler(ns,br)		Shoveler(fo)					
Redhead(fo)		Redhead(ns)	Redhead(fo)							Redhead(ro)
Ruddy(fo)		Ruddy(ns)								
										Common merganser (fo)

Cont'd. next page

Table 4, Cont'd.

Semiperm.(1'+)	Seasonal(<1')	Tall emergent	Short emergent	Saltgrass	Annuals	DNC	Riparian	Upland	Ag. Lands	Riverine
Bufflehead(fo)										
Ringneck(fo)										
Canvasback(fo)										
							Osprey(ro)			Osprey(fo)
Bald Eagle(fo)	Bald Eagle(fo)						Bald Eagle(ro)			Bald Eagle(fo)
			Northern harrier(ns,fo)			Northern harrier(ns,fo)				
			Swainson's hawk(fo)			Swainson's hawk(fo)	Swainson's hawk(ns,ro)			
			Red-tail hawk(fo)			Red-tail hawk(fo)	Red-tail hawk(ns,ro)			
			Rough-leg hawk(fo)			Rough-leg hawk(fo)	Rough-leg hawk(ro)			
								Ferruginous hawk(fo)		
							Golden Eagle (ro)	Golden Eagle (fo)		
			Prairie falcon(fo)			Prairie falcon(fo)		Prairie falcon(fo)		
Peregrine falcon(fo)	Peregrine falcon(fo)									
						Ring-necked pheasant(ns)			R.N.pheasant(fo)	
			Sora (ns,fo)							
		Virginia rail(ns,fo)	Virginia rail(ns,fo)							
American coot (fo)		American coot (ns)								
	Sandhill crane(ro)		Sandhill crane(lo,fo)		Sandhill crane(fo)				Sandhill crane(fo)	
	Whooping crane(ro)		Whooping crane(lo,fo)		Whooping crane(fo)				Whooping crane(fo)	
	Snowy plover(fo)			Snowy plover (ns,fo)?						
	Semipalmated plover(fo)									

Activity Code: ns=nesting, fo=foraging, mo=molting, ro=roosting, br=brood rearing, lo=loafing

The major factors influencing the type and distribution of historical vegetation communities at Monte Vista NWR are:

1. The geomorphic and topographic surfaces of the San Juan Mountain foothills; alluvial fans; and the historic channels of Spring, Rock, and Cat Creeks and their associated floodplains (Figs. 2,3,6,8).
2. Soil type and salinity (Fig. 7).
3. On-site hydrology that is affected by seasonally and annually variable inputs of water and whether the site is subirrigated by high groundwater tables.

These ecosystem attributes were used to construct the HGM matrix (Table 5) and subsequent map of potential historical vegetation community distribution (Fig. 16). The first step in this process was to determine the distribution of major vegetation/community types from GLO surveys (Fig. 10), early botanical accounts (e.g., Ramaley 1929), and older maps and aerial photographs (Figs. 17,18). This information defines the locations of upland foothills, the historic Rock, Spring, and Cat Creek channels, salt desert shrub, and the distribution of larger wetland areas along Rock and Spring Creeks. These major landscape and vegetation features were overlaid on contemporary geomorphology, soil, and topography maps to determine correspondence. While older maps and accounts have limitations and may not be completely georeferenced, they do provide the opportunity to specifically define some areas, such as the historical Rock and Spring Creek channels, the general area of larger wetlands along Rock Creek in the northern part of the refuge, and the San Juan foothills with Luhon-Garita-Travelers association soils (SCS 1980). Once the major creek, wetland, and foothill areas were identified, the balance of Monte Vista NWR was divided into potential historical communities/habitat types based on soil types. Information in the 1980 soil survey for Rio Grande County is especially useful to distinguish major communities associated with specific soil types and series (SCS 1980). We acknowledge that soil mapping in the 1980 soil survey may reflect some changes in soil chemistry and hydrologic characteristics that occurred since

Table 5. Hydrogeomorphic (HGM) matrix of historic distribution of vegetation communities/habitat types on Monte Vista National Wildlife Refuge. Relationships were determined from old aerial photographs (Fig. 16), plat and GLO maps (Figs. 6,9,15) geomorphology maps (Fig. 5), soil maps (Fig. 7) and survey publications (SCS 1980), various historical botanical accounts of the region (Hayden 1873, Hanson 1929, Ramaley 1929, 1942, Carsey et al. 2003) and land cover maps prepared by the U.S. Fish and Wildlife Service.

Habitat type	Geomorphic surface	Soil type	Flood frequency[a]
Undershrub-grassland	San Juan Mountain foothill slopes	Luhon,Garita	OSL
Salt desert shrub	Alluvial fan, Floodplain	Hooper,Arena, San Luis, etc.	OSL, MSWF
Semipermanent wetland	Creek corridors	Vastine	OBF
Seasonal wet Meadow	Floodplain margins	Alamosa, Acasco, Mishak, Torsido, Typic Fluvaquents	OBF, SWF

[a] OSL – on-site local precipitation, MSWF – minor surface sheetwater flow, OBF – overbank flows of Spring and Rock Creek, SWF – surface sheetwater flow.

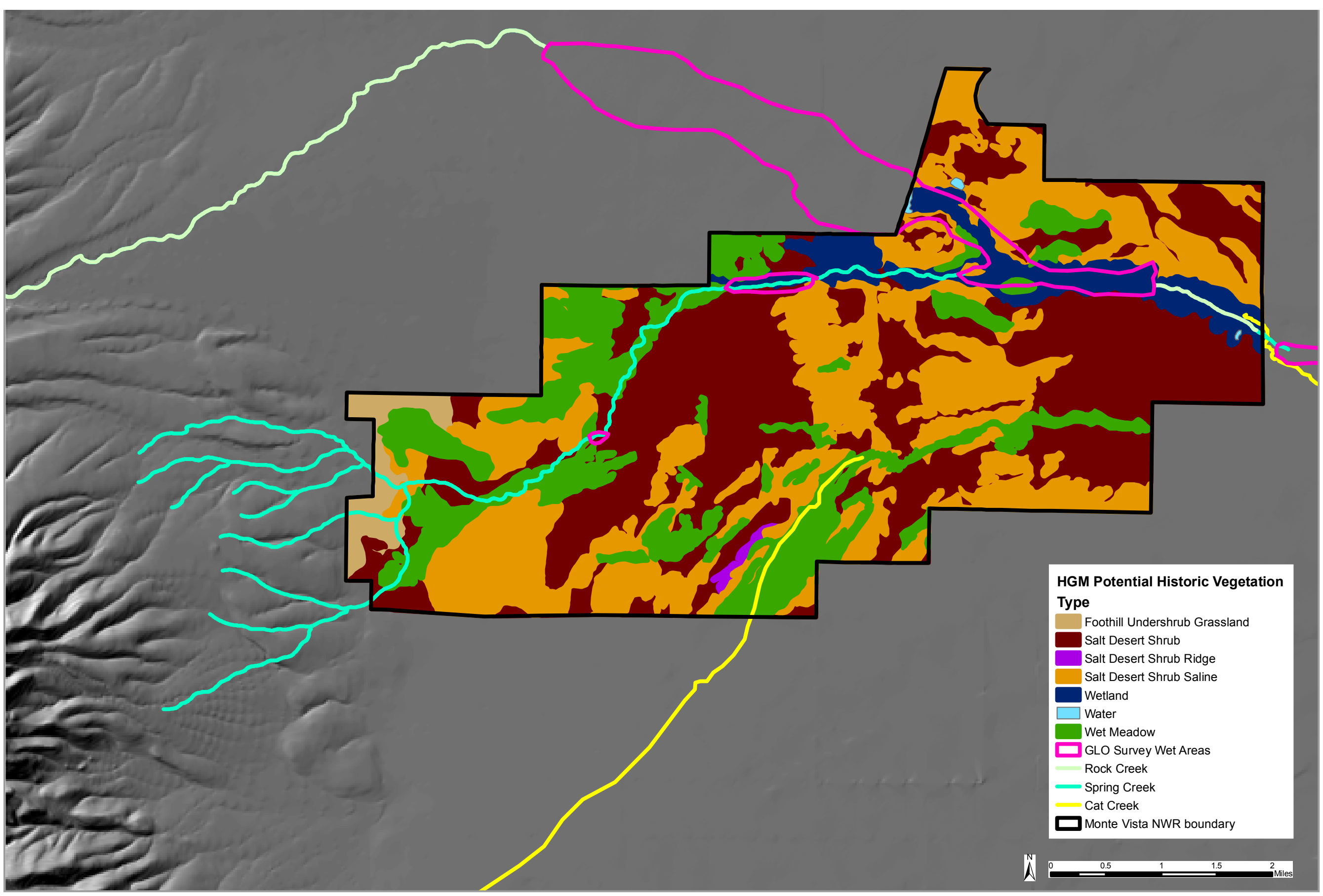


Figure 16. Potential historical vegetation community distribution on Monte Vista National Wildlife Refuge (mapped using HGM attribute relationships in Table 5).

Figure 17. Wheeler Geologic Map of the San Luis Valley depicting land coverages. Yellow= Agricultural (irrigated); Pink= Arid and barren; Light green= Grazing; and Dark green= Timber. From U.S. Geological Surveys West of the 100th Meridian Land Classification Map of Southwestern Colorado: Expeditions of 1873, 74, 75, and 76. Atlas Sheet No. 61.

the late-1800s because of the extensive alterations in surface and groundwater inputs, creation of roads, levees, ditches, canals, water diversions, and land leveling. However, basic soil texture and strata should not be different than in earlier times unless excavation and movement of soil material occurred.

The salt desert shrub community covered much of the large alluvial fan surface on Monte Vista NWR. These sites had sandy loam soil characteristics that had short duration saturation and supported more upland species such as greasewood and alkali sacaton. Consequently, the historical distribution of this community type can be generically mapped by overlapping these features. The salt desert shrub habitat at Monte Vista NWR undoubtedly had considerable diversity in specific plant distribution related to site-specific soils, hydrology and topography. The presence of this shrub heterogeneity is supported by remnant vegetation diversity that suggests lateral heterogeneity and older botanical accounts that suggest interspersion of highly saline "chico" flats and ephemeral wetland basins in this community type (Ramalay 1929, 1942). Consequently salt desert shrub communities likely were historically separated into highly saline vs. low saline assemblages based on soil salinity (Fig. 7). As mentioned above, the uncertainty about soil salinity changes at Monte Vista NWR that occurred in response to major valley-wide and site-specific land and water uses make modeling of this historical vegetation/habitat diversity difficult. Nonetheless, some of the attributes of salt desert shrub habitat diversity are known and are articulated in the HGM matrix

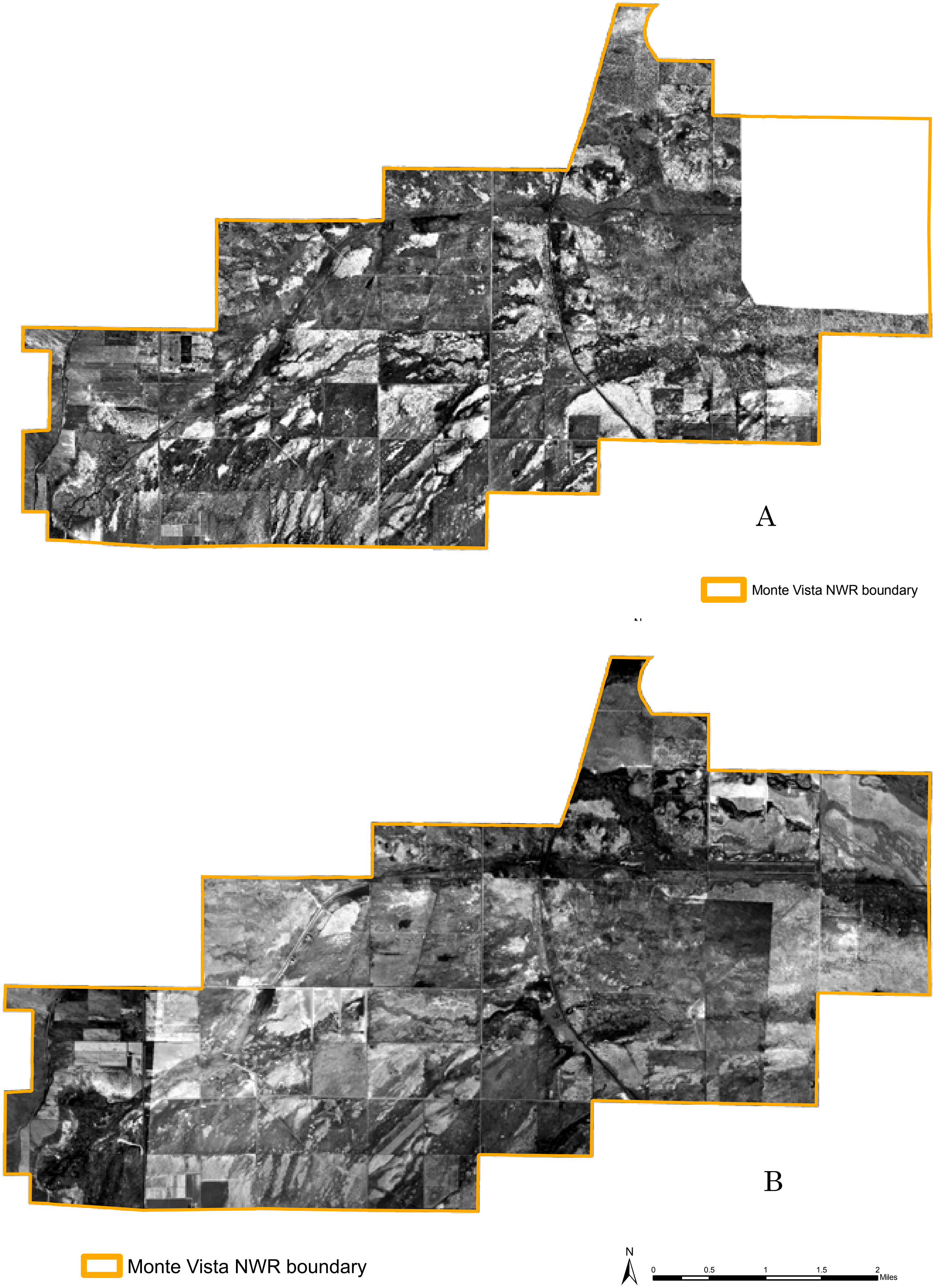


Figure 18. Aerial photographs of Monte Vista National Wildlife Refuge, a) 1941 and b) 1960.

(Table 5) so that some guidance can be provided to future restoration activities.

The GLO maps and survey notes (Fig. 10) suggest that wetlands historically present on Monte Vista NWR were mostly confined to areas near creeks and that wet meadow communities occurred in slightly higher adjacent areas in the floodplain surfaces. Based on the strong seasonal inputs of water from the relatively small Rock, Spring, and Cat Creeks, it seems likely that most of the wetlands were seasonally flooded. However, some of the wetland areas identified on the GLO maps may have been deeper and had semi-permanent flooding regimes at least during wet years. Most of the identified historical more frequently flooded wetland areas on Monte Vista NWR occurred in Vastine soils; these were at and near the confluence of Rock and Spring Creeks. Vastine soils are typically located in floodplain areas dominated by clay-loam textures that have moderate permeability and a water holding capacity conducive to vegetation species associated with wetlands such as sedges and rushes (SCS 1980). In contrast, wet meadow habitats have a variety of clay and loam soils including Alamosa, Acasco, Mishak, Torsido, and Typic Fluvaqeunts series (Table 5). The distribution of wet meadow areas on Monte Vista closely tracks the Spring and Cat Creek corridors (Figs. 6, 16). The GLO surveys did not document small depressional temporary or ephemeral wetlands associated with shrublands. Undoubtedly, some of these small depressions historically were present and they were temporally flooded or had saturated soils from onsite precipitation or some groundwater discharge depending on the season and presence of a confining soil strata layer (Rocchio 2005).

Southern Ute
Chief Buckskin Charlie
1895

CHANGES TO THE MONTE VISTA ECOSYSTEM

SETTLEMENT AND LAND USE CHANGES

Native people apparently first occupied the SLV 10,000 to 12,000 years before the present (BP) (e.g., Jodry et al. 1989). These people had a highly mobile lifestyle that depended largely on big game hunting. Initially, populations apparently were relatively small with localized and often seasonal settlements, many of which were along the Rio Grande and former lakes, rivers, and wetlands of the SLV where the availability of water, wildlife, and shelter was more predictable. For example, numerous archaeological sites occur in the headwater spring discharge area of Spring Creek on Monte Vista NWR (USFWS 2003). By about 2,000 BP, human populations in the SLV appear to have increased, small villages were established, and agriculture was developed along some waterways. Pueblo people were attracted to the SLV and, along with the Comanche, Utes, and other tribes, maintained some occupation of the region through the mid-1800s. Spanish explorers in 1540 found evidence that Pueblo people were diverting water from the Rio Grande in "acequias" or irrigation ditches (Jodry et al. 1989).

Spanish settlers first entered the SLV between 1630 and 1640 and several Spanish expeditions to the SLV occurred in the 17th and 18th centuries, although extensive settlement did not occur until the 1800s. An excellent summary of European settlement and history in the SLV is provided in Athearn (1975) and Simmons (1999 as excerpted from USFWS 2003). The following historical information is excerpted from these sources.

The historic territory of "New Mexico" was claimed for Spain in 1598 and Juan de Onate established a base camp near the confluence of the Rio Grande and Rio Chama. Shortly thereafter, hunting and exploratory expeditions into the SLV occurred. Bison were hunted in the valley at that time and native people were present (Fitzgerald et al. 1994). Sante Fe, New Mexico was established in 1610 and became the capital of Spain's Northern Province.

Conflicts between the Spanish and Pueblo and Ute people accelerated in the early- to mid-1600s. After expulsion of Spanish people in New Mexico in 1680, Spain retaliated in 1694 and Don Diego de Vargas reestablished control of Sante Fe. Later, Vargas traveled through and established camps in the SLV to hunt bison and elk. Many place names in the SLV came from early Spanish expeditions and people. By the mid-1700s, the Comanche gained power in the Rio Grande Valley and displaced the Ute who lived in the SLV. By the early-1700s, some mining had begun in the surrounding mountains, and during the mid- to late-1700s, the controlling government of New Mexico attempted to curtail Comanche raiding parties in the region, including the SLV. The Utes joined the Spanish in combating the Comanche and in 1786, the Comanche were defeated and signed a peace treaty with the Spanish.

From 1780 to the early-1800s, the Utes were the principal claimants to the SLV and Colorado mountains. Other tribes including the Navajo, Apache, Comanche, Kiowa, Arapaho, and Cheyenne also visited the SLV. Spanish and native people began to trap furs in the nearby mountains at this time and the fur trade expanded markedly after the U.S. gained control of much of the western U.S. via the Louisiana Purchase. Zebulon Pike was dispatched to explore the Rocky Mountain region in 1806. His party established a winter camp along the Conejos River, but was later detained by the Spanish. This was the last U. S. sponsored expedition into the SLV until 1848, when John Fremont came through the valley in search of a route through the Rocky Mountains.

In 1821, revolution created the independent Republic of Mexico, which then became separated from Spain. At this time the former New Mexico territory became a free province and American and Mexican trappers regularly used the SLV as a resting and staging location. While the buffalo trade developed across the west in the 1830s, the SLV was less affected because it had few bison and the Utes diligently defended their hunting territory.

No permanent town-settlements occurred in the SLV until the 1800s. Hispanic settlement of the SLV began on Mexican land grants in the late-1840s and early-1850s, mainly Spanish missionaries and sheepmen (Buchanan 1970). Farmers soon learned that the floodplains of rivers and creeks were the only areas that could be cultivated and these areas also provided the most dependable forage for livestock, which dominated the economy of the area at the time (Holmes 1903). By the late 1840s, scattered settlements were present throughout the SLV. In 1846, war occurred between Mexico and the U.S., which culminated in the Treaty of Guadalupe-Hildalgo in 1848 that ceded control of Colorado and other western areas to the U.S. After the U.S. occupied the southwestern region, a network of army posts was established with settlement, farming, and ranching expanding rapidly in the late 1850s. The Homestead Act of 1862 and the arrival of roads and railroads in the 1860s and 1870s facilitated substantial population growth. During the 1860s a series of roads were built in the SLV to facilitate travel north from Fort Garland. In 1879 a narrow gauge rail line was constructed to Alamosa, Colorado and agricultural goods were shipped to Denver, Colorado and other eastern cities. By the late-1800s sheep and cattle grazing were extensive in the Valley and valley farms were producing large quantities of potatoes, hay, and peas.

Following major expansion of settlement into the SLV in the mid-1800s, farmers decided that irrigation was necessary if valley agricultural commerce was to survive. The history of efforts to develop means to irrigate SLV lands for agricultural production is extensive and is a classic example of efforts (that occurred repeatedly throughout the western U.S. where water is limited) to acquire, divert, and use limited surface and groundwater (Siebenthal 1910, Follansbee et al. 1915, Brown 1928, Powell 1958, Buchanan 1970, Emery et al. 1973, Athearn 1975, Hanna and Harmon 1989, Leonard and Watts 1989, BLM 1991, Ellis et al. 1993, Emery 1996, Jodry and Stanford 1996, McGowan and Plazak 1996, Wilkins 1998). This report does not attempt to chronicle the complex water developments, laws and regulations, and past and current attempts to plan and manage irrigation water supplies and diversions throughout the SLV. The following is a brief account of some of the major events that ultimately affected water supplies, movement, and uses on Monte Vista NWR based on the above references.

The first ditch to move water from local rivers to the interior of the SLV was the San Luis Peoples Ditch constructed in 1852. The first large ditch to move water from the Rio Grande, the Silvia Ditch, was constructed in 1866 (Holmes 1903). The "Ditch Boom" hit the SLV in the 1880s when many British and eastern investors sponsored construction of canals to provide irrigation water to agricultural areas in the SLV. The largest investments came from the Travelers Insurance Company of Connecticut, which financed the building of the Monte Vista and Travelers canals that diverted water from the Rio Grande to the SLV including areas now part of Monte Vista NWR. Other major canals also subsequently were built in the 1880s, such as the Empire Canal through Monte Vista NWR, which transformed the valley floor into a major agricultural production region.

Agricultural production in the SLV was enhanced by drilling thousands of wells into both the shallow unconfined and the deeper confined aquifers starting in the late-1800s. Water flows from wells drilled into the unconfined aquifer are subject to annual variation related to fluctuating recharge rates from infiltration of local precipitation and runoff, whereas flows from wells drilled into the confined aquifer are artesian and are buffered from climatic conditions. Recharge of the unconfined aquifer may be artificially increased by the addition of groundwater resources applied for irrigation. By 1980 about 2,300 pumped wells existed in the unconfined aquifer in the SLV (Emery 1996). Artesian water under the SLV was discovered about 1887 and within four years about 2,000 flowing wells had been developed (Emery 1996). By 1904 more than 3,200 artesian wells had been dug and by 1916 about 5,000 artesian wells were present and flowing in the SLV. By 1970 that number had increased to over 7,000 wells. Well pumping typically causes the unconfined aquifer to be seasonally lowered; the last time this aquifer was at or near capacity was the mid-1980s and the mid-1990s. Pumping from the confined aquifer has continually depleted the aquifer storage and it has not been at capacity since the early-1950s www.waterinfo.org/taxonomy/term/1620). At Monte Vista NWR, many areas of the former salt desert shrub lands on the higher elevation alluvial fan surface near creek channels was converted to annually irrigated wet meadows for livestock grazing and production of hay and cropland via extensive networks of irrigation infrastructure built in the late-1800s and early-1900s. Much of this early water-control infrastructure remains present on Monte Vista NWR.

The substantial diversion of water from the Rio Grande in the SLV in the late-1800s led to an "embargo" in 1896 and the Rio Grande Convention Treaty of 1906 between the U. S. and Mexico. The "embargo" ordered by the U.S. Secretary of the Interior prevented further irrigation development of any magnitude in the Rio Grande Basin of Colorado and New Mexico by suspending rights-of-way across public lands for use of Rio Grande water; the embargo was not lifted until 1925. Under terms of the Treaty of 1906, the U.S. guaranteed an annual water delivery in perpetuity of 60,000 acre-feet of water in the Rio Grande at the head of the Mexican Canal near El Paso, Texas. In 1929, a temporary compact for water use and delivery in the Rio Grande was ratified by Colorado, New Mexico, and Texas and in 1938-39 these states ratified the Rio Grande Interstate Compact, which provides for apportionment between states of the water of the Upper Rio Grande Basin on the basis of specified indices of flow at key gauging stations. This Compact greatly influenced diversion of water from the Rio Grande in the SLV and subsequent development of surface and groundwater infrastructure that has affected Monte Vista NWR (Ellis et al. 1993).

In addition to diversion of Rio Grande water and drilling of groundwater wells, other water-control infrastructure in the SLV captured and diverted groundwater discharge and drainage. Two major groundwater conveyance ditches, the Bowen and Parma Drains were dug in the early-1900s, both of which carry water through Monte Vista NWR (Fig. 19). Groundwater pumping and diversion of groundwater discharge ultimately caused many discharge areas, such as the Spring Creek Spring, to dry up and discontinue seasonal flows (USFWS 2003).

As early as the late-1800s, farmers in the SLV began noticing increases in soil salinity, or "alkali" as it was commonly known, in some upland areas (mostly former salt desert shrub community sites) away from the Rio Grande that were sub-irrigated for production of hay, pasture, and cropland (Holmes 1903). Buildup of alkali was most common in areas that formerly had been in salt desert shrub; soils in these areas were locally known as "adobe" and covered with "chico brush" (greasewood). Technically, the soils in these former salt desert shrub areas were initially defined as San Luis sandy loam (Holmes 1903). Saline soils with high carbonate levels are common in the salt desert shrub areas and when irrigated for prolonged periods during the growing season, waters take up small amounts of soluble salts and through capillarity moved salts to soil surfaces. Historically soil areas highly susceptible to this alkali condition were south and east of Monte Vista near the current Monte Vista NWR (Holmes 1903) while areas immediately along the Rio Grande and near the foothills around the SLV were less affected.

CONTEMPORARY HYDROLOGIC AND VEGETATION COMMUNITY CHANGES

Immediately prior to refuge establishment in 1952, the Monte Vista area was predominantly pasture/hay and cropland. Many areas of native salt desert shrub habitat near Spring, Rock, and Cat Creeks had been converted to irrigated pasture and hay land and numerous small levees, water diversion control structures, and ditches had been constructed to facilitate irrigation (Fig. 18a). The original development plan for Monte Vista NWR proposed considerable expansion of existing dikes, ditches, drains, water-control structures, and roads to increase the diversion of water from the Monte Vista and Empire Canals (and other smaller drain canals) to enhance existing, and create new, irrigated meadows and wetland ponds (USFWS 1962). The subsequent development of this extensive water diversion and storage infrastructure subdivided the refuge into many water management "sub-units", with a general intent of maximizing the amount of refuge land that could be flooded or seasonally irrigated to benefit wetland-dependent wildlife, primarily waterfowl. These early water diversion and irrigation developments generally were designed and constructed irrespective of soil type or historical vegetation community types (USFWS 1962). Following the first refuge water-control developments, additional

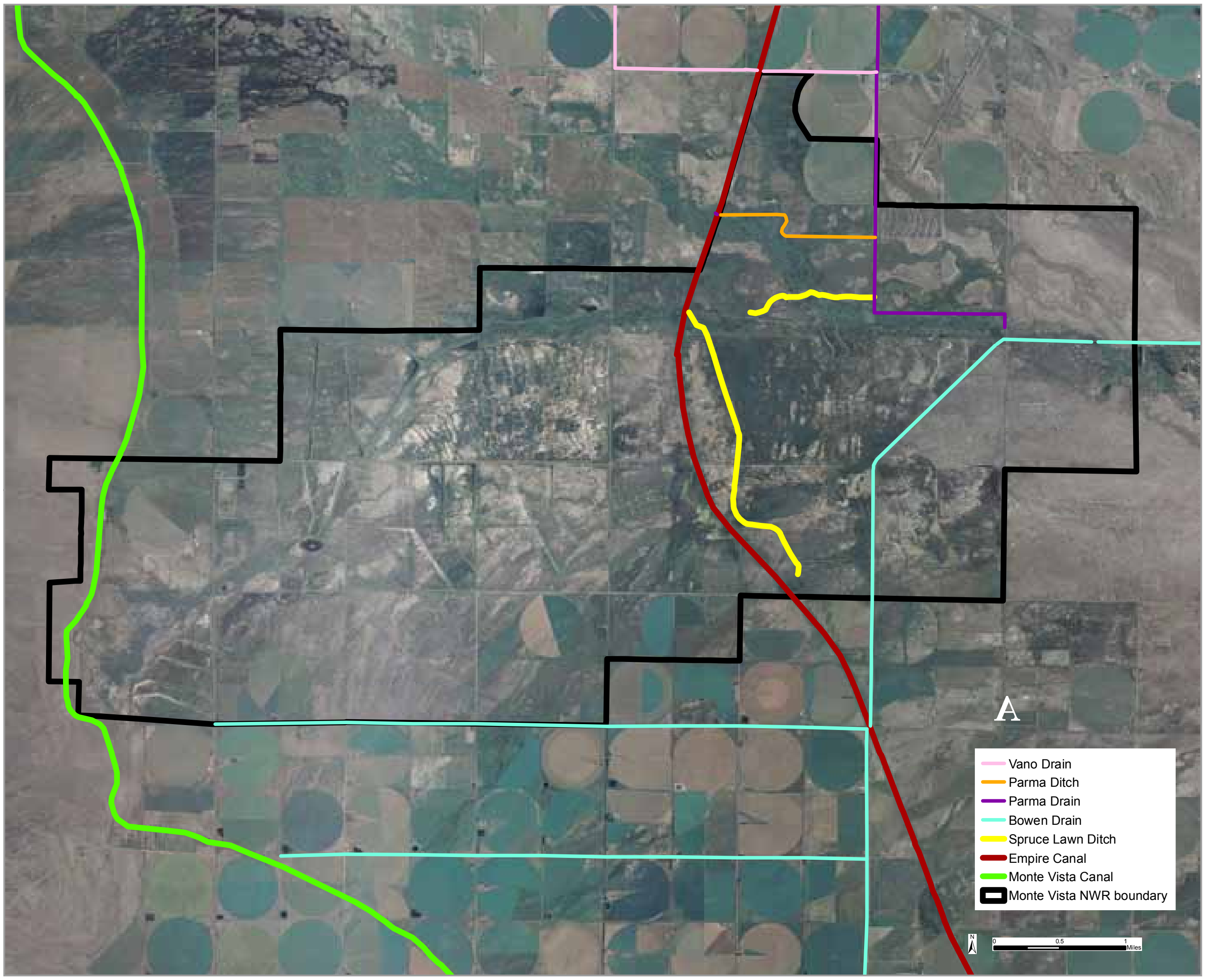
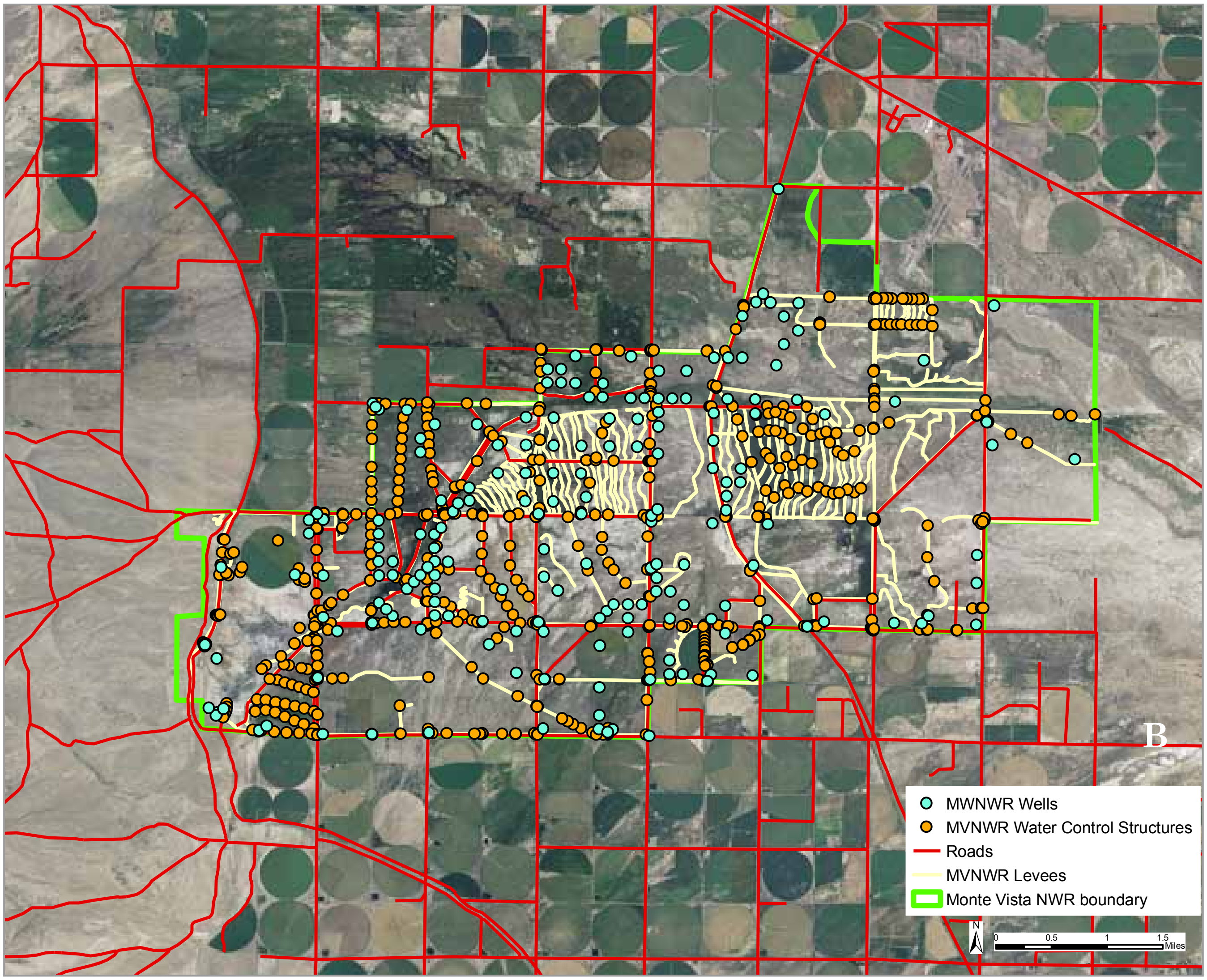


Figure 19. Location of: a) major ditches and drains and b) wells, water-control structures, levees, and roads on Monte Vista

levees, dikes, and water-control structures have been constructed and have created about 80 distinct irrigated wetland sub-units and more permanently flooded artificial diked "ponds", such as Parker Pond, along canals and drain ditches (Fig. 19).

The development of extensive networks of water diversion and conveyance ditches and canals, levees/dikes, and water-control structures on Monte Vista NWR have continued from the initial developments in the 1960s to the present time with a substantial increase in sub-compartmentalization of management units occurring during the mid-1990s to the mid-2000s (USFWS refuge annual narratives). Certain units on Monte Vista NWR have been extensively developed and compartmentalized by relatively large angle-dikes (e.g., Units 6, 10, 15, 16, 19), closely-spaced contour levees (Units 7 and 9), and conveyance ditches (Units 15, 16, 6, 8, 10) (Fig. 20). Many of these water-diversion/control developments have effectively blocked, diverted, and significantly modified former natural surface water flow pathways and patterns and attempted to create meadow and wetland habitats in areas that were formerly salt desert shrub habitat. For example, the four large angle-dikes constructed in Unit 19 intercept the natural historical drainage pathway of Spring Creek by diverting and impounding water in four small and closely spaced sub-units, and modifying and reducing Spring Creek flows further downstream. Modification of natural surface flow pathways occurs throughout the Spring and Rock Creek drainage corridors in Units 1-11, 14, and 15 and within the smaller formerly intermittent flow corridor of Cat Creek in Units 16, 17, and 22.



National Wildlife Refuge.

In the early-1950s, all of the wells on Monte Vista NWR were free-flowing from artesian pressure in the deeper confined aquifer and Spring Creek was still discharging groundwater (Striffler 2012). However, by the 1970s, the Spring Creek groundwater discharge point "head" stopped flowing and the number of free-flowing artesian wells on the refuge declined greatly. In the early-1970s, the Colorado State Engineer placed a moratorium on new wells drilled into the confined aquifer in the SLV. Since 1981, no well construction permits for new water appropriations, other than exempt domestic wells, have been issued in the SLV. Currently, during summer months almost all artesian wells on Monte Vista NWR cease flowing when maximum groundwater pumping occurs on and off the refuge for irrigation purposes (U.S. Bureau of Reclamation 1995).

In the mid-1980s, efforts began to recharge groundwater in the SLV. Currently, from November to January, six major irrigation companies divert and hold Rio Grande water in their canals to assist groundwater recharge. These winter diversions and recharges occur only if river water is not needed to meet the 1939 Rio Grande Compact obligations. The Monte Vista and Empire Canals are two of the irrigation canals used for the recharge program and certain areas on the refuge receive this winter recharge water if available (USFWS 2003, Striffler 2012).

Currently, Monte Vista NWR has 254 wells that historically provided at least some water to the refuge. Water from these wells is adjudicated for irrigation, wildlife, domestic, and stock water purposes (Striffler 2012). Of the 254 wells, 206 are small artesian wells that flow seasonally at rates

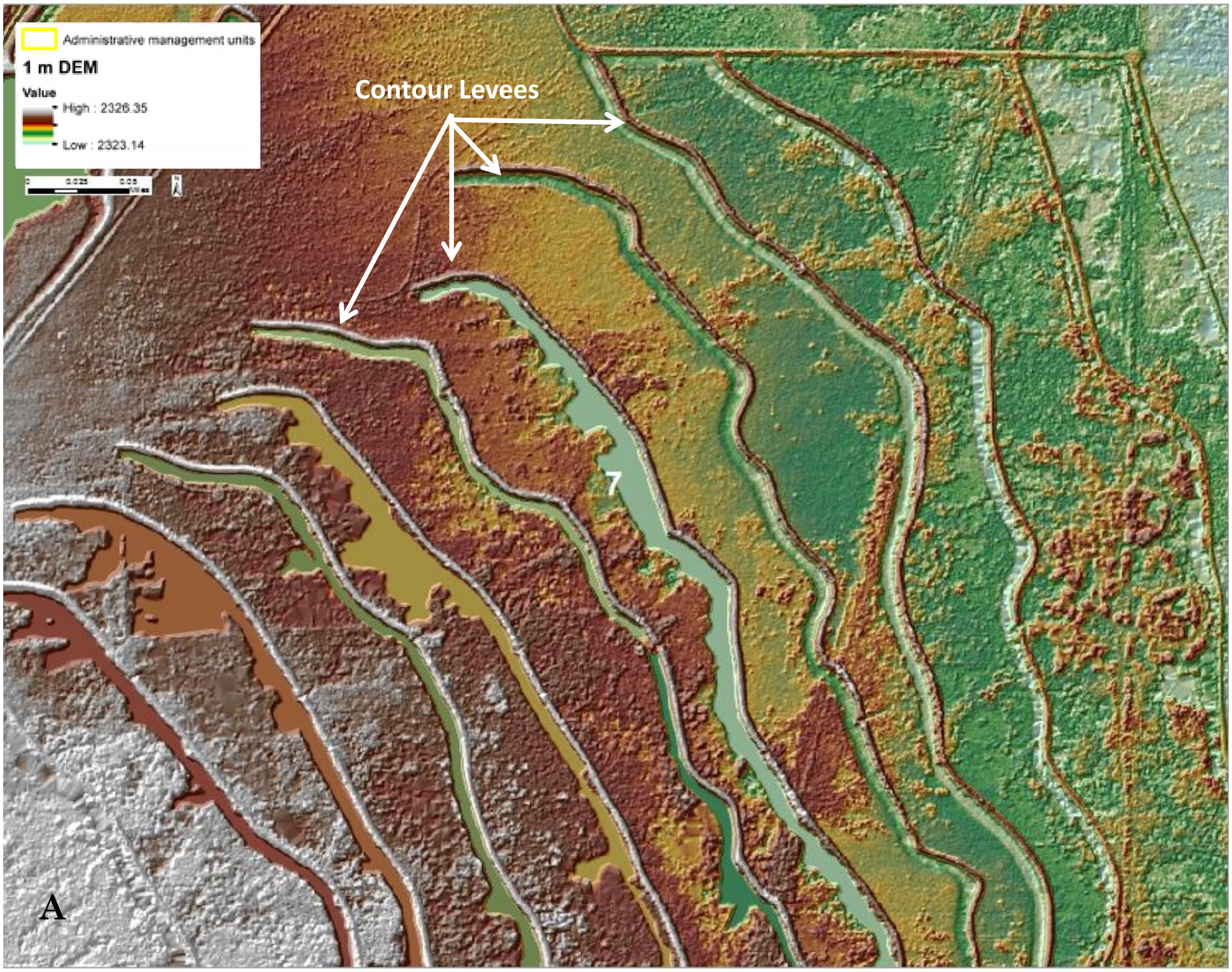


Figure 20. LiDAR DEM background showing: a) Unit 7, close-spaced contour levees, b) Units 15 and 16, angle-dikes, and c) Unit 10, conveyance channels on Monte Vista NWR.

< 50 gallons/minute (gpm). Eleven artesian wells are identified as flowing > 50 gpm but are listed as inactive and are no longer used. Three other larger artesian wells are adjudicated for an average flow of about 1,800 gallons/minute. Monte Vista NWR also has 21 large pumped wells with an average adjudicated flow of about 1,700 gpm.

Water availability and management at Monte Vista NWR is heavily controlled by SLV-wide water diversion infrastructure and associated Rio Grande Compact and water rights law. Monte Vista NWR receives an annual average of about 8,500 acre-feet of irrigation water from the Rio Grande primarily through the Empire and Monte Vista canals and water draining from neighboring private lands into several drainage ditches (e.g., Parma, Bowen, and Vano drains, etc., Fig. 19). As mentioned previously, the water delivery and diversion to the more than 80 wetland management sub-units on Monte Vista NWR is achieved using the complex infrastructure that includes more than 30 major and 100 minor dikes, over 400 water-control structures ranging from road culverts to larger creek dams and diversion points, and 61 miles of ditches (Fig. 19). Currently, the capability exists to seasonally irrigate and control water on more than 80% of the land surface on Monte Vista NWR (Striffler 2012).

The quality of water entering Monte Vista NWR could be potentially contaminated from inputs via the Rio Grande, subsurface groundwater, and drainage ditches (Striffler 2012). In general elemental contamination of water entering Monte Vista NWR is not high although drainage ditches contain the poorest water quality among water sources in the SLV (Archuleta 1992, Anderholm 1996). Copper and zinc in ditch waters exceed

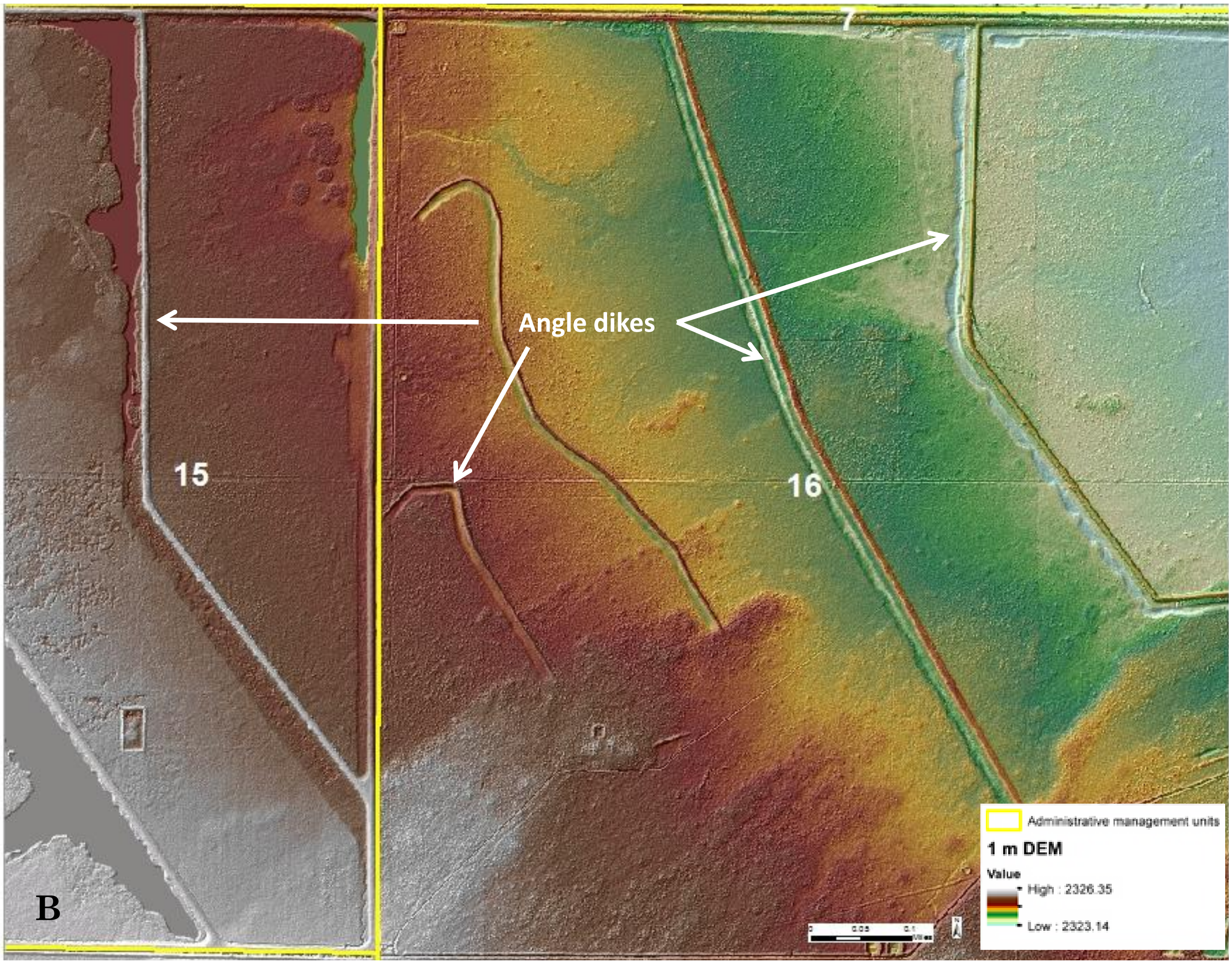


Figure 20, (continued). LiDAR DEM background showing: a) Unit 7, close-spaced contour levees, b) Units 15 and 16, angle-dikes, and c) Unit 10, conveyance channels on Monte Vista NWR.

aquatic life standards for the Rio Grande Basin. Mean concentrations of beryllium cobalt, iron, and manganese can exceed sediment guidelines and mean boron concentration has exceeded dietary levels for waterbirds.

Early in the development of Monte Vista NWR, over 100 small (1/4- to one-acre) "ponds" were created by constructing ring-dikes around artesian wells that were present when the property was purchased by the USFWS (Fig. 21). These ponds were intended to capture and hold artesian well water and provide small wetlands for waterfowl and other local wildlife species. Many of these ponds were not capable of holding water for more than short periods, because of low artesian flow and porous soils. The soil salinity of some pond sites also was high. Currently, many of these ponds are dysfunctional. Additionally, over time more than 100 islands were built in wetland units for nesting waterbirds and ducks. As some small artesian wells quit discharging water, other deeper and bigger wells were drilled.

Annual narratives for Monte Vista chronicle the many water and habitat management activities on the refuge through 1994 (Table 6). Management on the refuge is designated by 24 major management or "administrative" units (Fig. 12) and since the early-1960s, management has focused on providing habitat for breeding ducks (USFWS 2003), which includes early annual flooding, planting and maintaining dense nesting cover, and some predator control (Schroeder et al. 1976, Gilbert et al. 1996, USFWS 2003). This management emphasis was fostered by the attraction of high numbers and densities of breeding dabbling ducks to flooded wetlands on the refuge (Gilbert et al. 1996). Long-term studies

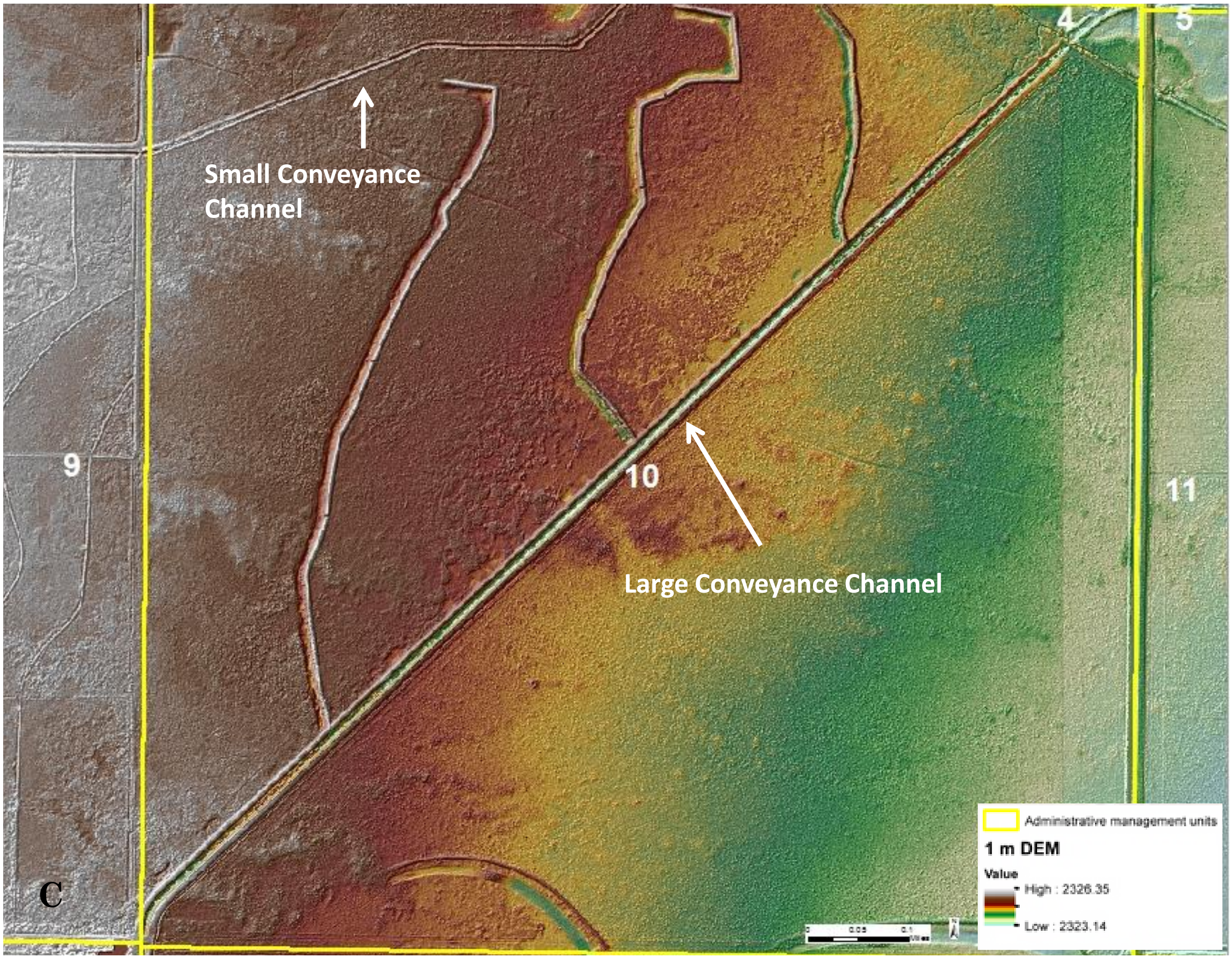


Figure 20, (continued). LiDAR DEM background showing: a) Unit 7, close-spaced contour levees, b) Units 15 and 16, angle-dikes, and c) Unit 10, conveyance channels on Monte Vista NWR.

of nesting ducks on the refuge indicated generally good nesting success and recruitment of young from the refuge into the 1990s.

Water management on Monte Vista NWR has been generally consistent over the past 30+ years (refuge annual narratives). The following paragraphs describe the typical water diversion and management efforts on the refuge to provide seasonal habitats and resources for wetland-dependent wildlife, especially waterfowl (taken from Striffler 2012). This description generalizes patterns and how annual differences occur for the specific location and timing/duration of water diversion and storage.

Groundwater is pumped (also including some artesian well flow) or diverted from the Parma Drain into about 2,000 acres of wetland units in February and March (Fig. 22a). This water provides roosting and loafing habitat for sandhill cranes and waterfowl, foraging and pair habitat for breeding waterbirds, and irrigation of nesting cover, mainly Baltic rush. During April through mid June, over 5,000 acres of wetland units, especially Units 1, 2, 3, 4, 6, 7, 9, 10, and 18, are flooded using surface water diverted from the Rio Grande through the Empire and Monte Vista canals (Fig. 22b). This water is moved to various units via lateral diversion ditches and water-control structures. Groundwater wells supplement the diverted Rio Grande water during dry years. This water management provides nesting and foraging habitat for breeding ducks and waterbirds and irrigation of nesting cover. From mid-June to August, over 1,300 acres of management units 1, 2, 4, 7, 11, 14, 15, and 18 are shallowly inundated similar to water diversions and movements in April and May (Fig. 22c) primarily to

Figure 21. Photograph of a ring-dike around an artesian well on Monte Vista National Wildlife Refuge.

provide nesting and brood rearing habitat. During September and October about 2,000 acres in units 8, 17, 19, and 20 are flooded using groundwater from wells (Fig. 22d) to provide additional brood habitat; loafing, roosting, and foraging habitat for fall migrant cranes, waterbirds, and waterfowl; and some hunting opportunity. In addition, groundwater recharge water is sometimes available from the Monte Vista and Empire Canals. Water in the Monte Vista Canal is directed to Unit 19 and if any excess water is available it is diverted into Spring Creek for flooding Unit 7. Available water in the Empire Canal is diverted into Units 9 and 10 and other northern areas.

Total annual water diverted onto the refuge has varied from less than 10,000 to more than 25,000 acre-feet from 1980 to the present (Fig. 23). Much of the annual variation in refuge water diversion relates to the amount of surface water available that can be diverted from the Rio Grande, which is influenced by annual precipitation and discharge in the upstream watershed. The USFWS acquired groundwater rights and rights to use water from the Rio Grande when refuge lands were acquired. The USFWS also subsequently established rights under Colorado water law to use groundwater. Groundwater wells supply on average about 8,200 acre-feet of water/year and about 8,500 acre-feet of Rio Grande water is used on average each year although use of this river water has varied from none in 2002 to over 30,000 acre-feet in 1992 (Fig. 23). Total water use reached a peak of about 38,000 acre-feet in 1992 and a low of 5,333 acre-feet in 1977. Generally, water availability and use on the refuge follows an alternating high and low pattern of regional precipitation that spans about 25 years (see earlier section on historical climate patterns).

In addition to the extensive artificial management of water on Monte Vista NWR, other habitat management has included: 1) physical manipulation of vegetation using land leveling, brush hogging, grazing, burning, tillage, and chemical treatments; 2) small grain production for sandhill crane and other wildlife use; and 3) control of invasive plant species (USFWS 2003, Table 6). Cattle grazing occurred on Monte Vista NWR from establishment until 1994 when a federal court ruling postponed grazing on the refuge and the USFWS initiated a five-year study to assess the effectiveness of different habitat management tech-

Table 6. Summary of water developments and management of Monte Vista NWR 1953-1994, taken from refuge annual narratives.

Year	Unit	Development Activities
1952		Monte Vista National Wildlife Refuge is established
1953	Sheridan Tract	80 ac cleared of brush, disced, floated and staked for leveling; chiseled down to 30"
	Rodman Tract	36 ac disced
	Sheridan Tract	3.5 ac fenced for goose pen
	Sheridan and Todman Tracts	8 to 10 miles of drain put in with 3 crossing and checks
	Sheridan Tract	Water control structures placed in north and south ditches
	Sheridan and Todman Tracts	7 ponds constructed around artesian wells
1954	Sheridan Tract	North and South ditches extended
	Sheridan and Rodman Tracts	Checks, weirs, dividing boxes and crossings added to ditches
	Unit 13	Chisled, disced, and planed for future planting
	Unit 1	New takeout on the Monte Vista Canal installed
	Across units	107 small ponds built around artesian wells; 4 of them are 15 ac while the others are 1/4 to 1 ac in size
1955	Across units	200 pond banks were planted with grasses
	Sheridan Tract	34 islands were created in upper Spring Creek
	Unit 7	11 irrigation structures installed
	Unit 13	160 acres was leveled
	Unit 4	Unit plowed
	Unit 1	60 ac cleared of brush
	Across units	35 new ponds
1956	Unit 22	1400' of drain installed
	Units 22, 23, and 3	200 ac harrowed, land planed, plowed, and planted
	Units 25, 26, and 29	5 new ponds developed
	Unit 24	2 contour levees and 2 water control structures installed
	Unit 20	One large pond and two small one acre ponds developed
	Unit 19	One 4 ac pond developed
1958	Units 20, 22-5	Drain ditches completed
	Unit 23	63 ac leveled and landplaned
	Unit 22	39 ac leveled and landplaned
	Unit 30	Initiated pond development and dike construction
1959	Unit 2G	2 contour levees, each 1.5 miles long; another 3 of 0.75 miles long
	Unit 6g and 6h	A 0.75 mile levee constructed between the two units
	Across units	9 24" control gates installed on ponds
1960	Across units	30 miles of small ditches reworked and cleaned
	Unit 3g	One mile of drain completed
	Unit 2f	100 ac cleared of brush for future farmland
1961	Across units	48 miles of ditches reworked and cleaned
	Unit 26	2 miles of raised head ditch constructed
	Unit 2f	107 ac leveled, 80 tons of manure spread over it, 50 ac disced to maintain brush control, 82 ac deep plowed and chiseled
	Unit 2	2 new goose pens constructed
	Unit 9f	Brush removed from 20 ac of land, half of unit plowed
1962	Across units	68 miles of ditches cleaned and reworked
	Unit 13	28 6" water control structures installed
	Unit 22	40 ac was brush hogged to start land leveleing
	Units 6 and 14	New ponds completed
	Unit 19	Development of this unit including 11.4 miles of levees and installation of structures

Table 6. continued

Year	Unit	Development Activities
	Unit 6	Development of this unit including 4.4 miles of levees and installation of structures
	Unit 14	Development of this unit including 1.55 miles of levees and installation of structures, 1.14 miles of roadway, 44 ac of land leveled with 22 ac of it chiseled
	Unit 22	Development of this unit including 40 ac land leveled and 110 ac deep chiseled
1963	Across units	100 miles of ditches cleaned
	Unit 15g	New head ditch installed
	Units 13f-6, 14f-1, and 13f-7	Leveling, landplaning, and deep chiseling
1964	Units 16, 21, and 22	Small ponds developed for watering cattle
	Across units	85 miles of ditches cleaned
1965	Unit 13	A new reservoir of 12 ac/ft capacity constructed for temporary storage of irrigation water
	Unit 6	Parshall flume installed in lateral 3
1966	Unit 15	New and extension levees completed
	Unit 16	New and extension levees initiated but not completed
1967	Unit 18	Constructed 1.25 miles of drain ditch around 80 ac field for farmland
1968	Unit 4	2 way water control structured installed to distribute water from Parma drain
	Unit 19	Goose pen area completely redone
	Unit 13 reservoir	Land leveling with removal of 12,600 cubic yards of dirt; clay and silt form unit 19 were spread over the interior of the reservoir for sealing
1969	Unit 23f-1	Land leveling, deep chiseling, discing, and land planing of 45 ac
1971	Unit 18f-1	Leveling, disking, land-planing, and deep chiseling
1980	Units 1 and 7	Levees constructed along the east side
	Noll property and Unit 10	2 contour levees, north and south, were completed in the newly acquired parcel and tailed out into unit 10
1984	Unit 16	Development of this unit including contour levees and 9 water-control structures
1990	Unit 15	moist soil vegetation management applied for first time on a pond
1991	Unit 24	moist soil vegetation management applied for first time on the Barclay pond

niques, which included grazing (Diebboll 1999). Concerns about grazing were in part derived from a long-term study of dabbling duck nesting on the refuge that indicated nest density was negatively affected by grazing (Gilbert et al. 1996) although many other factors such as vegetation characteristics, hydrology, and location were never considered. After the conclusion of the studies grazing was discontinued on the refuge (Table 6, USFWS 2003) until the late-2000's. Over time burning has become infrequent.

The extensive development of wetland management infrastructure before and after refuge establishment, the relatively consistent annual water regime management (flooding) among management units, and clearing of shrubland for croplands greatly altered the vegetation community/habitat composition on Monte Vista NWR since its establishment. Major modifications/degradations included a major reduction in the extent and composition of salt desert shrub habitat and a shift in remnant shrubland community composition toward the invasive weed, tall whitetop, and wetland vegetation, especially baltic rush (comparison of habitat areas on Fig. 16 vs. Fig. 24). Currently about 24% of the refuge is in salt desert shrub habitat, which

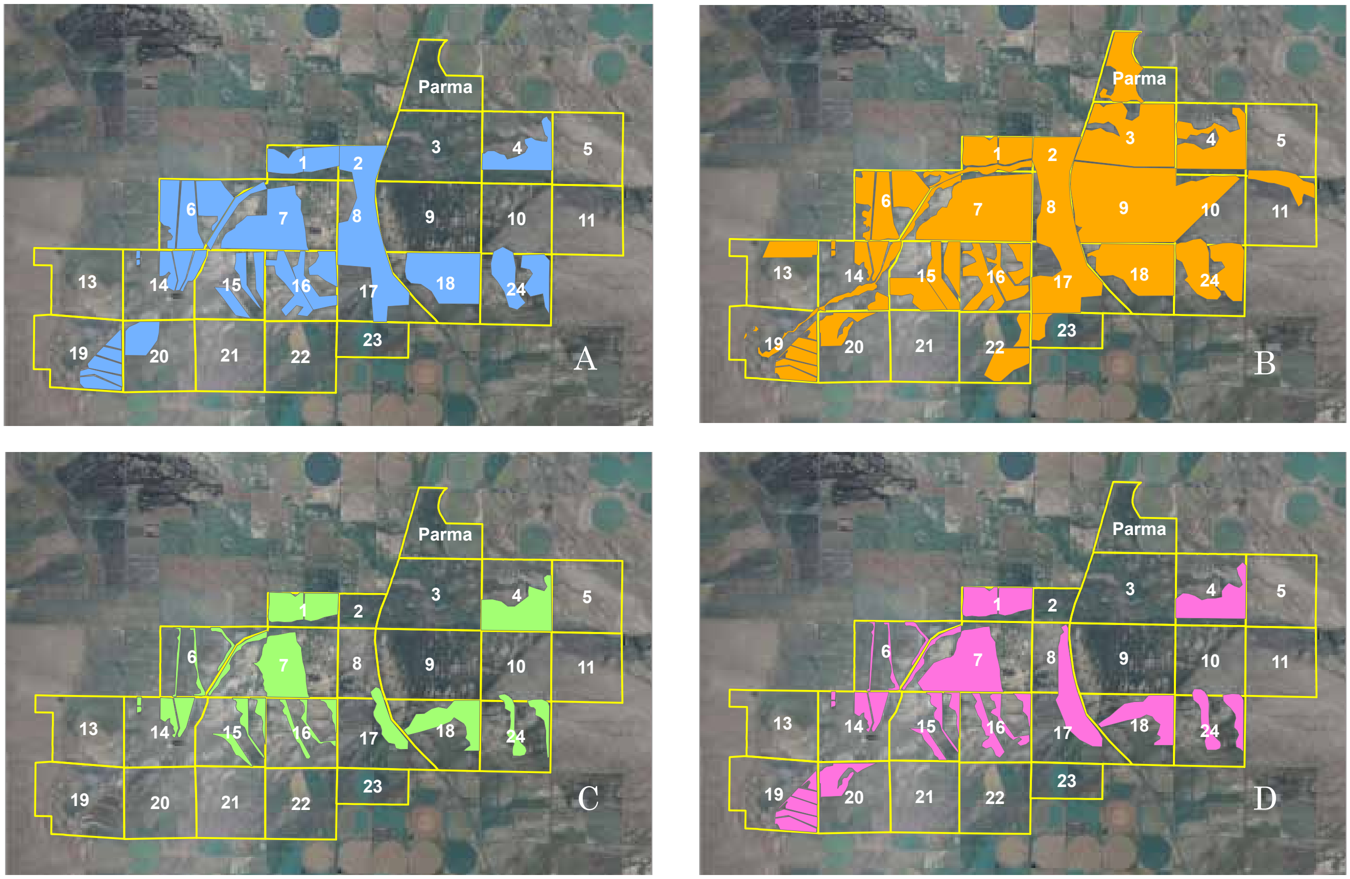


Figure 22. Water management strategies for Monte Vista National Wildlife Refuge: a) Feb-Mar, b) April to mid-June, c) mid-June to August, and d) Sept-Oct (modified from Striffler 2012).

when compared to the potential historic vegetation identifies a decrease of about 75% of this community type over time. National Wetland Inventory maps of the refuge prepared in the 1980s demonstrate the large areas of artificially managed seasonal and semi-permanent wetland units that represent converted salt desert shrub and creek corridor natural seasonal wetlands (Fig. 23). Most artificial wetlands mapped on Monte Vista are a “wet meadow” category that now is primarily composed of baltic rush and tall whitetop (Figs. 24-27). The area immediately south of Unit 9 is an example of where former shrubland has been converted to artificially irrigated wetland and the site is now invaded by tall whitetop. This site has Arena soils series, which typically supports salt desert shrub and saltgrass habitats (Fig. 27). In other areas, including those that have Hooper soils indicative of former shrub lands, whitetop also is extensive.

The extensive spread of tall whitetop on Monte Vista NWR is closely associated with the disturbance of soils and changes in hydrology caused by artificial irrigation and diversion of water to former shrublands. Although initially spread through the ditch system, native shrub vegetation communities were converted to wetter states through prolonged seasonally flooded hydrologic regimes, which allowed tall whitetop to out-compete natives (Gardner 2002). About 80%+ of the tall whitetop present on Monte Vista NWR is associated with levees, ditches, within a short distance of them, or has continued to spread out from these initially colonized areas (Fig. 27). Common areas for tall whitetop to initially germinate include transition areas from one vegetation community to another such as small elevation changes between wet meadow and salt desert shrub (Gardner 2002). Germination of tall whitetop seeds have been documented under a wide range of temperatures with only very cold or highly constant temperatures preventing growth (Miller et al 1986). Therefore, the wide range of diurnal temperatures which occur in the SLV are perfect for establishment of this species. Studies have shown that this weed may over time alter local soil characteristics such as chemistry and structure. Tall whitetop is capable of taking sodium out of the soil profile and depositing it on the surface, thereby preventing germination of salt-intolerant species (Blank and Young 1997). Monotypic stands prevent light penetration to the surface further restricting competition from native species. Of note are Units 5, 10, and 11 south of the Bowen Drain, which have retained relatively intact greasewood shrublands that have not been converted to artificial seasonal wetlands and are not

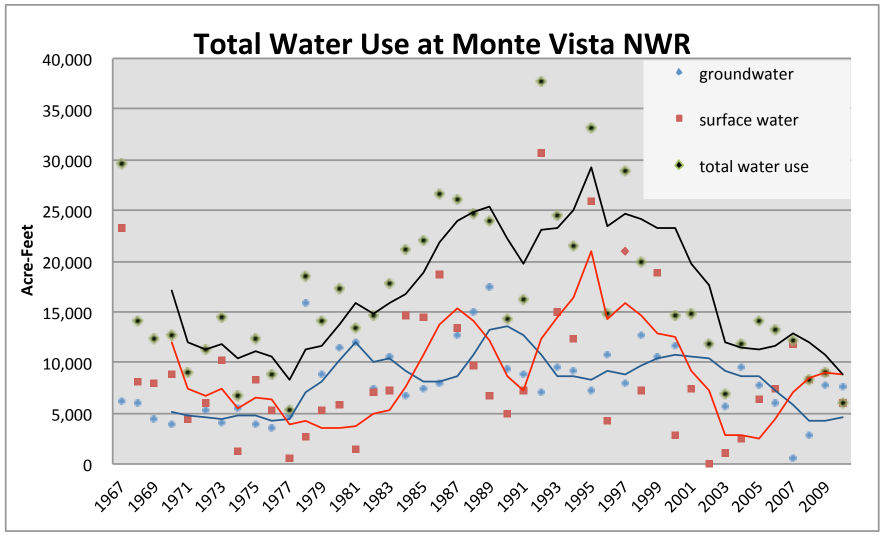


Figure 23. Total water use at Monte Vista National Wildlife Refuge 1967-2009 (from Striffler 2012).

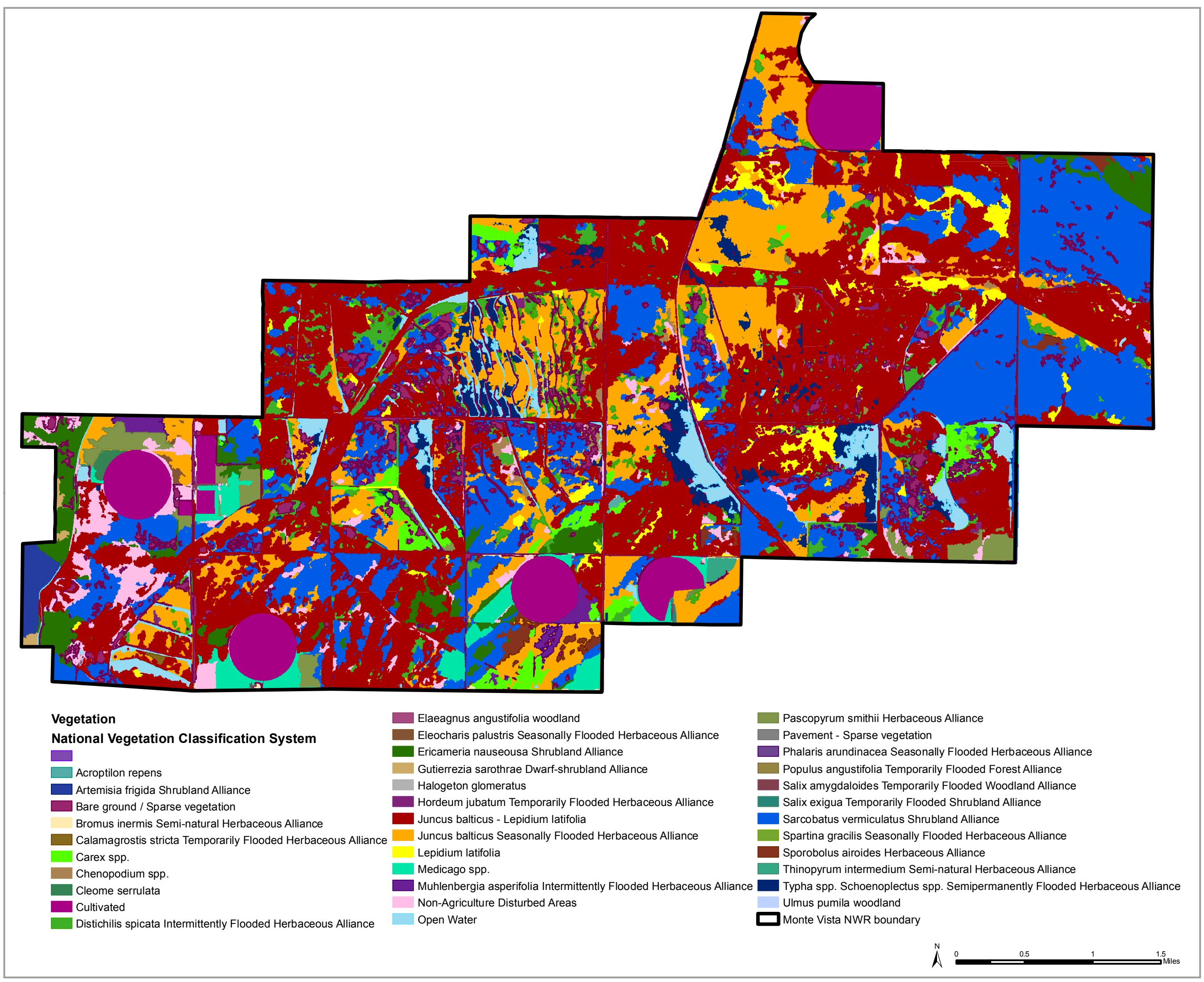


Figure 24. 2005 National vegetation classification system map of vegetation alliances on Monte Vista National Wildlife Refuge.

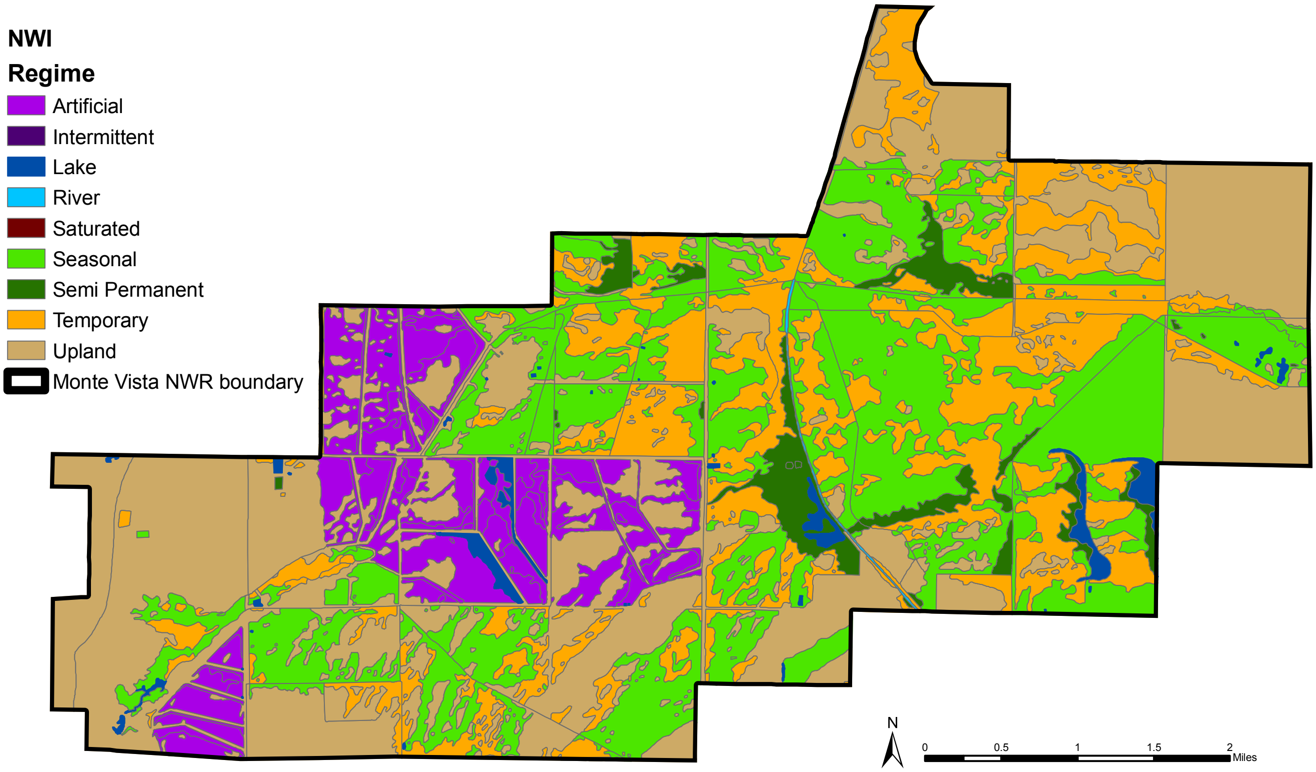


Figure 25. National wetland inventory of wetland classification types on Monte Vista National Wildlife Refuge.

invaded by tall whitetop. The presence of more intact shrub habitat in these units supports the conclusion that changes in hydrologic regime have helped establish tall whitetop in many areas that were formerly shrublands. Refuge management has attempted to limit the spread of invasive plant species, especially tall whitetop, using repeated mowing, herbicide application, and targeted grazing using sheep in some areas (USFWS 2003).

Several invasive species in addition to tall whitetop, including Canada thistle (*Cirsium arvense*), hoary cress (*Cardaria draba*), and knapweeds (*Centaurea* spp. and *Acropitilon repens*) are now widely distributed on the refuge and control of these species has been conducted with various chemical and physical treatments. These species are dispersed via irrigation ditches or equipment and commonly germinate in disturbed areas on a variety of soil types. However, they may occur in slightly different habitats as knapweeds typically exist in dryer areas whereas Canada thistle and hoary cress can survive in a wider range of moisture regimes. Canada thistle seeds may be viable in the soil for up to 20 years and has an extensive and often deep root structure that requires a combination of treatments for control. Mowing and grazing has proven effective in reducing the extent of this weed (Clark 2000). In more permanent water areas, cattail has developed relatively monotypic stands, which have been controlled by mechanical and water management. The combination of increased spring and summer irrigation flooding followed by rapid drying and high ET has elevated soil salinity levels and caused the spread of saltgrass.

After Monte Vista NWR was established, the refuge farmed about 900 acres to provide small grains to wintering waterfowl, cranes, upland birds, and deer (USFWS 2003). By the early 2000s, this farm acreage had declined to about 500 acres planted in rotations of small grains, alfalfa, and fallow. The alfalfa haying was used to increase soil fertility through nitrogen fixation, increase organic matter content, and to control invasive weeds. Most of the cropland and alfalfa lands are irrigated with center-pivot sprinkler systems in the Parma Unit and in Units 13, 20, 22, and 23 as opposed to flood irrigation methods used in meadows and wetlands. Lands removed from crop production were planted to perennial grasses and legumes.

Monte Vista NWR contains relatively abundant populations of the globally imperiled slender spider flower (*Cleome multicaulis*), which

Figure 26. General location of tall whitetop and baltic rush on Monte Vista National Wildlife Refuge.

occurs on moist alkaline soils found in the transition areas located between wet meadows and salt desert shrub communities (Rocchio et al. 2000). Giant bur-reed (*Sparganium eurycarpum*), a state imperiled species also is found on Monte Vista NWR. This plant is a persistent emergent found in wetlands with semi-permanent water regimes. Several animal species of concern are present on Monte Vista NWR, including the bald eagle (*Haliaeetus leuceocephalus*), American bittern (*Botaurus lentiginosus*), black tern (*Childonias niger*), burrowing owl (*Athene cunicularia*), ferruginous hawk (*Buteo regalis*), and white-faced ibis (*Plegadis chihi*). Population trends for bald eagle (Fig. 28), white-faced ibis (Fig. 29), duck broods (Fig. 30), and sandhill crane (Fig. 31) indicate annually variable numbers. Generally white-faced ibis and sandhill crane numbers on the refuge have increased over time, while numbers of wintering waterfowl and eagles have decreased (USFWS 2003).

Relatively large numbers of breeding dabbling ducks were attracted to Monte Vista NWR to nest after extensive wetland development and management for spring-summer flooding of these sites began in the early-1960s. Consequently, the refuge became an important contributor to local and regional waterfowl populations (Szymczak 1986, Gilbert et al. 1996). The artificial and enhanced wetlands and wet meadows also attracted and supported relatively large populations of many other waterbirds, such as sandhill cranes, ibis, egrets, and shorebirds (D'Errico 2006). Populations of some of these species, such as sandhill cranes, became trademarks of the refuge along with breeding ducks. Refuge wetlands and meadows also formerly supported relatively large populations of waterfowl in winter and waterfowl hunting harvest

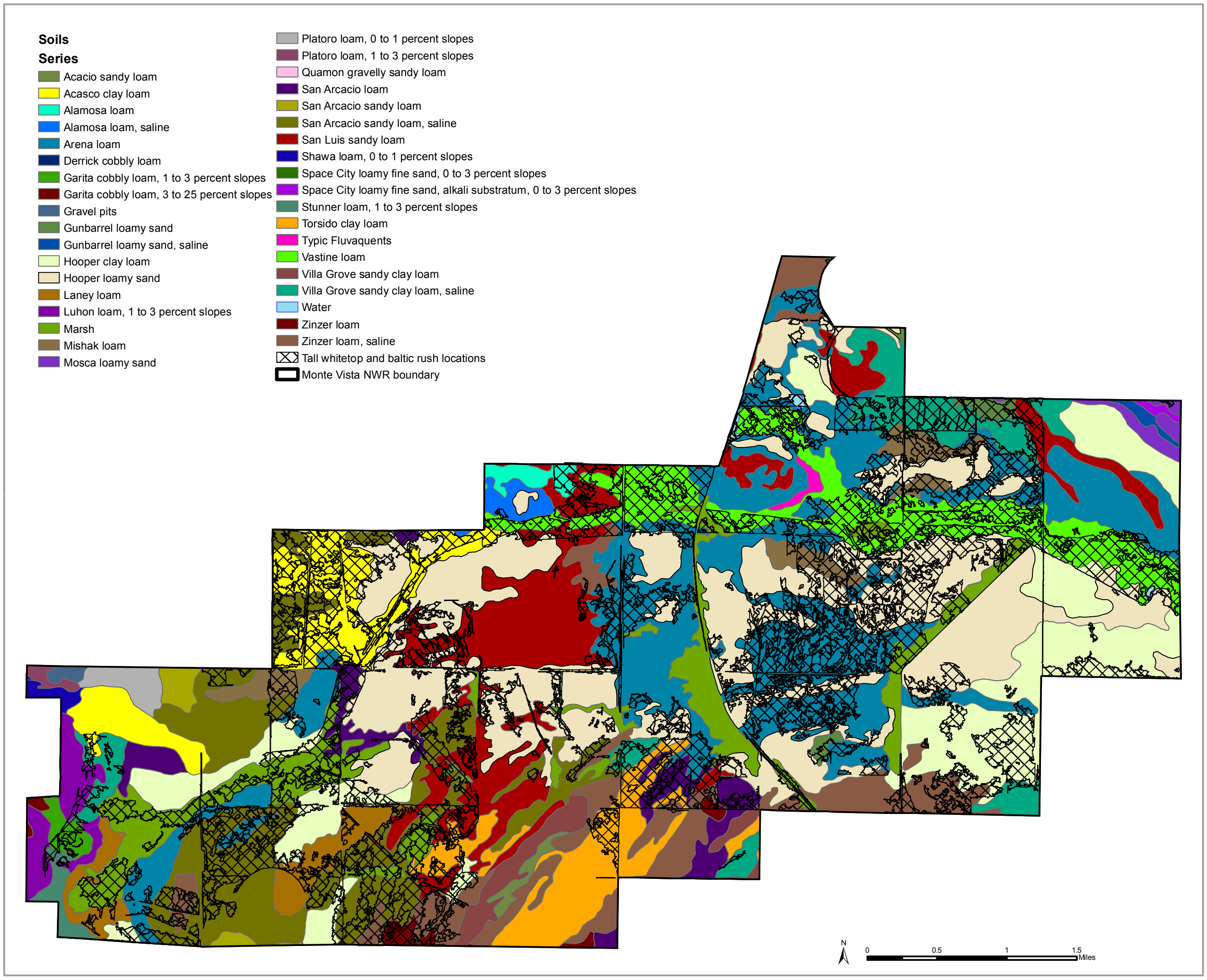


Figure 27. Location of tall whitetop and baltic rush on Monte Vista National Wildlife Refuge in relationship to soil type.

in the SLV traditionally has been among the highest in Colorado, mainly supported by locally produced ducks (Szymczak 1986). In some years, avian cholera outbreaks on the refuge have killed up to 6,500 ducks (USFWS 2003). Duck production on the refuge has averaged about 15,000 fledglings, but annual numbers fluctuate greatly depending on the amount of water available on the refuge and the overall wetness of the previous winter in the Rio Grande watershed.

It is generally believed that wetland-associated animal species, especially waterbirds, have increased on Monte Vista NWR compared to pre-irrigation and pre-wetland development periods (USFWS 2003). Several species of shorebirds, wading birds, and over-water nesters such as grebes commonly nest on the refuge. In contrast to waterbirds, populations of other animals that are associated with salt desert shrub likely have declined as this habitat was converted to irrigated meadow and seasonally flooded wetland units. In particular species such as burrowing owl, Gunnison's prairie dog (*Cynomys gunnisoni.*), raptors, plateau lizard (*Sceloprous tristichus*), and shrub and grassland birds now are rare, reduced in number and distribution, or are absent (USFWS 2003).

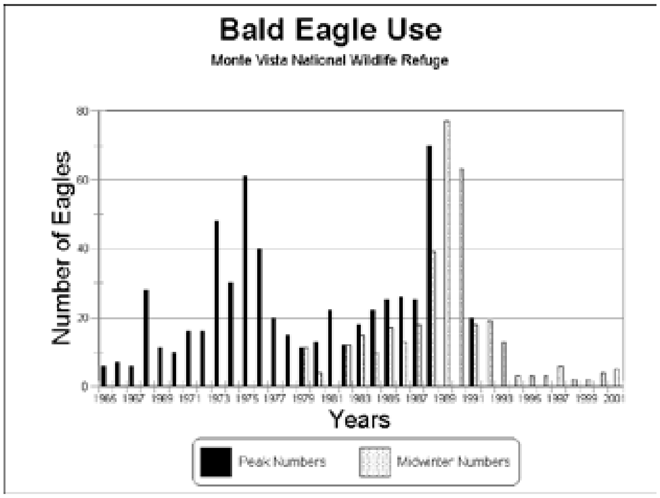


Figure 28. Number of bald eagles on Monte Vista National Wildlife Refuge, 1965-2001 (from USFWS 2003).

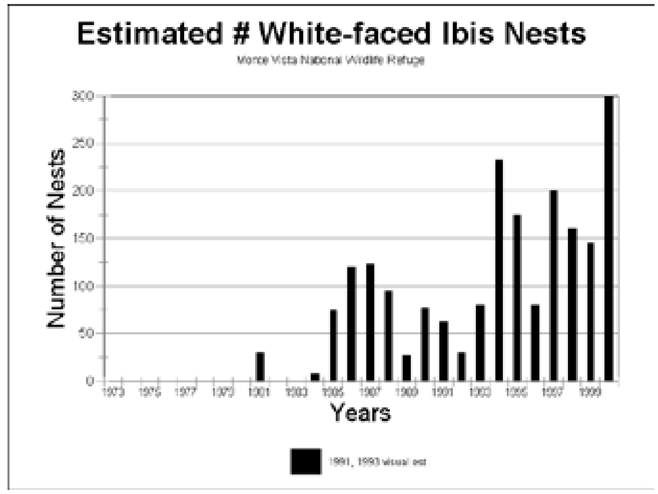


Figure 29. Estimated number of white-faced ibis nests on Monte Vista National Wildlife Refuge, 1973-2000 (from USFWS 2003).

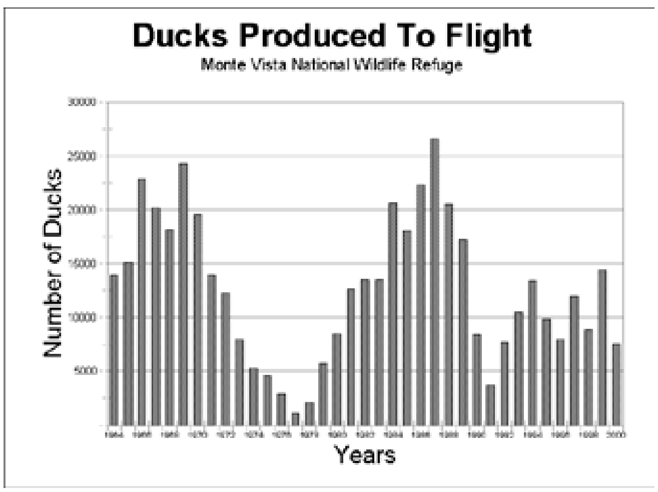


Figure 30. Estimated number of ducks produced to flight stage on Monte Vista National Wildlife Refuge, 1964-2000 (from USFWS 2003).

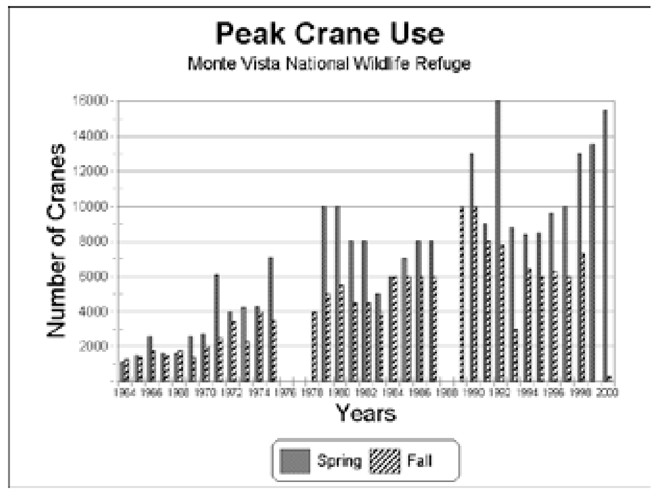


Figure 31. Peak numbers of sandhill crane on Monte Vista National Wildlife Refuge, 1964-2000 (from USFWS 2003).

OPTIONS FOR ECOSYSTEM RESTORATION AND MANAGEMENT

The SLV is a relatively arid environment and the distribution of vegetation communities historically present at Monte Vista NWR was influenced greatly by the timing and availability of surface water. Annual surface water inputs to the Monte Vista region were highly pulsed and dynamic in spring and early summer, depending on annual snowmelt and runoff from the San Juan Mountains. Summer rains allowed native plants to germinate, flower, and grow. Most wetlands probably dried by fall in most years, although deeper wetland depressions may have had semi-permanent water regimes during wet years. Consequently, annual variation in creek flows and summer rains likely caused significant annual variation in the amount and distribution of flooded wetland area and corresponding wetland vegetation communities. Salt desert shrub and meadow grassland communities were supported by sparse annual precipitation and irregular disturbance from fire and herbivory. The historical creek, wetland, meadow, and shrub/grassland habitats provided resources to help support populations of many animal species associated within the Rocky Mountain ecoregion (USFWS 2010).

The primary change to the ecosystem structure, function, and processes at Monte Vista NWR since the late-1800s has been the extensive alterations of SLV-wide and refuge site-specific distribution, chronology, and abundance of surface and groundwater. The history of water diversion, use, and management throughout the SLV, and specifically on Monte Vista NWR, both prior to and after refuge establishment is complex and reflect attempts by man, common throughout the arid western U.S., to obtain water for agricultural and community uses where surface water is limited. At Monte Vista NWR, the many issues that have affected water diversion, surface water flow into and across the refuge, extraction and use of groundwater, and management of available water, including the development of extensive artificial infrastructure, has created the highly modified landscape now present. The many modifications to the refuge and surrounding area have resulted in many ecological consequences; most of which have been detrimental to the long-term sustainability of native communities and resources. For example, attempts to increase irrigation/water diversion capabilities to extensive areas on the refuge to increase wetland habitats has: 1) destroyed and degraded the once extensive and predominant salt desert shrub community (including resources used by species dependent on this habitat) on the refuge; 2) modified and/or eliminated natural surface water flow pathways and patterns across the refuge (and further downstream off refuge lands); 3) facilitated invasion and expansion of invasive plant species, especially tall whitetop; and 4) altered basic soil chemistry and topography attributes of the system. Most of the system modifications on Monte Vista NWR after it was established were motivated by desires to increase annually consistent dabbling duck production regardless of the refuges position in the landscape in relation to waterfowl population life cycle events. This objective was met through alteration of existing shrubland habitat to seasonal and semipermanent wetland habitats through extensive compartmentalization of the refuge into over 80 wetland sub-units that are separated by various roads, dikes, ditches and drains, and water-control structures along with over 100 small ring-dikes around artesian well sites.

While past planning efforts for Monte Vista NWR were largely based on the desire to continue previous water management among the extensively developed wetland sub-units for breeding ducks (see refuge annual narratives and discussion in USFWS 2003), current refuge planning is considering a more system-based and holistic approach for future management strategies and desired states for the refuge. Considerations for a more "system-based" management approach requires that managers address basic questions about how to, and if they can realistically, restore more natural and sustainable communities and resources on Monte Vista NWR. This HGM report provides an evaluation of existing hydrogeomorphic information to help understand potential general options for restoration efforts and certain management actions that will be needed to sustain and support restorations. This information is useful only if the refuge seeks to achieve at least some restoration of native ecosystems, which is a strategic conservation decision outside the scope of this report. Assuming that at least some restoration of native communities is desired on Monte Vista NWR, the paramount issue influencing future management and restoration is the need to change how management addresses the timing, distribution, and movement of water on the refuge. These future decisions clearly require a careful and deliberate focus on changing the artificial water diversion and management on the refuge. Ultimately, these considerations will help define the contribution of Monte Vista NWR to conservation throughout the larger landscape scale of the SLV and the Upper Rio Grande ecoregion.

GENERAL RECOMMENDATIONS FOR ECOSYSTEM RESTORATION AND MANAGEMENT

As previously stated, this HGM evaluation is an attempt to help identify restoration and management options that will protect, restore, and sustain natural ecosystem processes, functions, and values at Monte Vista NWR. Clearly, the physical form, hydrology, and plant and animal communities at Monte Vista NWR are highly modified from the historical condition. Despite the many artificial alterations to the ecological integrity and character of the refuge, many opportunities do exist to restore at least some attributes of the native ecosystem, including restoration of natural water flow pathways, hydrological patterns, and the corresponding distribution of native vegetation community types. This HGM evaluation does not address where, or if, the many sometimes competing uses of the refuge can be accommodated, but rather it provides information to support The National Wildlife Refuge System Improvement Act of 1997, which seeks to ensure that the biological integrity, diversity, and environmental health of the (eco)system (in which a refuge sets) are maintained (USFWS 1999, Meretsky et al. 2006). Administrative policy that guides NWR goals includes mandates for: 1) comprehensive documentation of ecosystem attributes associated with biodiversity conservation, 2) assessment of each refuge's importance across landscape scales, and 3) recognition that restoration of historical processes is critical to achieve goals (Mertetsky et al. 2006). Most of the CCP's completed for NWR's to date, including the 2003 Monte Vista NWR CCP, have highlighted ecological restoration as an objective as it helps meet the authorizing purpose of the refuge. In general, historical conditions (i.e., the period prior to substantial human-related changes to the landscape, which at Monte Vista is the late 1800s) are considered the benchmark condition to guide restoration efforts (USFWS 2002, Meretsky et al. 2006). General USFWS policy, under the Improvement Act of 1997, directs managers to assess not only historical conditions, but also "opportunities and limitations to maintaining and restoring" such conditions. Furthermore, USFWS guidance documents for NWR management "favor management that restores or mimics natural ecosystem processes or functions to achieve refuge purpose(s) (USFWS 2001).

Given the above USFWS policies and mandates for management of NWR's, the HGM-approach used in this study can assist decisions about future management of Monte Vista NWR, at least where some restoration of historical communities is a goal. The HGM approach objectively seeks to understand: 1) how this ecosystem was created, 2) the fundamental physical and biological processes that historically "drove" and "sustained" the structure and functions of the system and its communities, and 3) what changes have occurred that have caused degradations and that might be restored to a less altered state within a "new desired" environment. The HGM approach also helps understand restoration opportunities for the Monte Vista NWR and can assist in helping to define the refuge's "role" in meeting larger conservation goals and needs at different geographical scales (e.g., USFWS 2010). In many cases, restoration of functional ecosystems on NWR lands can help an individual refuge serve as a "core" of critical, sometimes limiting, resources than can complement and encourage restoration and management on adjacent and regional private and public lands.

HGM evaluations are not species-based, but rather seek to identify options to restore and maintain system-based processes, communities, and resources that ultimately will help support local and regional populations of endemic species, both plant and animal, and other ecosystem functions, values, and services. Management of specific land parcels and refuge tracts should take into account the different resources needed by a variety of species throughout their life cycle. In some cases this means that relatively "artificial" habitats and structures, such as "ponds" may be important to provide critical resources to some species. The development of specific management strategies for Monte Vista NWR requires an understanding of the historic context of the Monte Vista area relative to what communities occurred in response to natural seasonal and interannual dynamics, the resources provided by these communities, and when and where (or if) species of concern actually were present and used these resources. Consequently, recommendations from the HGM evaluation in this study are system-based first, with the goal of maintaining the ecosystem itself, with the assumption that if the integrity of the system is maintained and/or restored, that key resources for species of concern can/will be accommodated. This approach is consistent with recent recommendations to manage the NWR system to improve the ecological integrity and biodiversity of landscapes (Fischman and Adamcik 2011). Obviously, some systems are so highly disrupted that all natural processes and communities/resources cannot be restored, and key resources needed by some species may need to be replaced or provided by another, similar habitat or resource.

Future management of Monte Vista NWR should attempt to attain an appropriate balance of providing critically important historical resources used and required by native animal species while simultaneously ensuring integrity of the system within the constraints imposed by local and SLV-wide land and water uses. Based on the HGM context of information obtained and analyzed in this study, we believe that future management of Monte Vista NWR should seek to:

1. Restore natural surface water flow pathways and associated hydrological regimes where possible to restore and manage wetlands and wet meadows along Spring, Rock, and Cat Creeks.

2. Restore natural topography and promote natural hydrologic regimes to restore at least some areas of historically occurring salt desert shrub and undershrub grassland habitat including its natural heterogeneity of sub-habitat components.

3. Restore natural disturbance regimes such as herbivory, fire, and drought to promote the health and quality of all habitat types and reduce noxious weeds.

The following general recommendations are suggested to meet these ecosystem restoration and management goals for Monte Vista NWR.

1. Restore natural surface water flow pathways and associated hydrological regimes where possible to restore and manage wetlands and wet meadows along Spring, Rock, and Cat Creeks.

GLO surveys and other historic information including the 1941 and 1960 aerial photographs (Fig. 18) indicate that wetland and wet meadow habitats historically present on Monte Vista NWR were located along the Rock, Spring, and Cat Creek drainage corridors. Pulses of water in the creeks following local rains and snowmelt in spring provided water that recharged and shallowly inundated off-channel wetlands. Short duration sheetflow of water overflowing from creeks into and across wet meadows provided sustained hydrological regimes for these wetland systems. Groundwater discharge from the Spring Creek "spring head" supported flows in Spring Creek (and to some degree downstream in Rock Creek) year round and created some open water and "sheet ice" even during colder winter months.

Wetlands on Monte Vista NWR historically were subject to both seasonal and long-term dynamics of precipitation, runoff, and groundwater discharge. During wetter years, creek flows likely were greater and more prolonged and probably created semipermanent water regimes in some deeper wetlands. Conversely, during dry years, inundation of creek corridor wetlands was of short duration following snowmelt and flooding regimes were seasonal at best. The combination of seasonal and long-term dynamics of creek flows through natural drainage corridors was the primary ecological process driving wetland and meadow hydrology on Monte Vista NWR. As such, availability of wetland resources and historical use by waterbirds and other wetland-dependent wildlife occurred primarily in spring and early summer with some fall migration and wintering habitat available in Spring Creek due to sustained groundwater creating some open water resources.

This report identifies the many extensive modifications and degradations to surface and groundwater availability, diversion and redistribution, water-control infrastructure, and past refuge water management and resource objectives on Monte Vista NWR. For example, natural creek and surface water flow across Monte Vista NWR now is effectively prevented by the presence of the many ditches, large canals, roads, and levees/ditches. Natural discharge of groundwater also is essentially eliminated, for example the cessation of discharge at the Spring Creek "spring head." In addition to on-refuge degradations, regional SLV-wide issues that affect surface water on Monte Vista NWR include the major valley water diversion infrastructure that exists. Collectively, regional and on-site changes to the physical and hydrological attributes of the Monte Vista NWR ecosystem has dramatically disconnected and diverted water flow away from the former Spring, Rock, and Cat Creek channels or caused them to completely cease flowing.

Certain physical and hydrological alterations on Monte Vista NWR directly interrupt and disconnect creek drainages such as the levees/dikes, ditches, and wetland sub-units constructed in former creek corridors. Specifically, artificial impoundments in management units 3, 4, 5, 6, 9, 10, 19, 20, and 24 directly disconnect and divert water from Spring and Rock Creek corridors. The small impoundments in units 22 and 23 also disconnect and redivert the former intermittent/seasonal Cat Creek channel area. Other infrastructure indirectly affects creek flows because of management decisions to move water away from the creeks to irrigate and shallowly flood former salt desert shrub areas at higher elevations. In effect these water diversions substantially reduce total and seasonal discharge capacity in the former creek corridors. Impoundments and physical modifications within former salt desert shrub areas also disrupt overland sheetwater flows, runoff to creek corridors, and water infiltration on the alluvial fan that is vital to the sustainability of the shrublands and the inherent soil chemistry of these sites. Other created wetlands in units 17, 18, 13, and 1 are not in former wetland sites and have been partly created because of canal and ditch locations as well as seepage or sub-irrigation. Further, extensive contour levees in some units such as Units 7 and 9 artificially move water into some higher elevations of the units that historically were not wetland or meadow, but rather were salt desert shrub habitats.

It is understood that past management and monitoring objectives for Monte Vista NWR have been primarily to maximize annual duck breeding pairs and production (along with supporting other waterbirds and wetland dependent species), to continue long-term nest transect surveys, and provide fall waterfowl hunting opportunity (USFWS 2003). However, continuation of consistent and prolonged flooding in impoundment units that formerly were salt desert shrub habitat, or even seasonal meadow, is not consistent with historical wetland distribution and surface water flow pathways on the refuge and continuation of water diversions and consistent annual flooding of these upland sites has the likely risk of long-term degradation of soil salinity, increased invasive species occurrence, decreased vegetation diversity, increased density and monocultures of certain emergent species such as cattail, and gradual decreases in wetland productivity. Future water and wetland management on Monte Vista NWR can restore at least some natural surface water flow pathways and corridors and more closely align water timing, depth, and duration to match soils and former wetland type distribution. For example, in areas that formerly supported mainly wet meadow communities, water management can induce short duration spring flooding as irrigation to sustain these diverse and productive meadow communities and resources that are so important for many animal species. Allowing these areas to naturally dry throughout the summer will help restore native vegetation.

The distribution of former wetland and meadow types on Monte Vista NWR based on soil type, elevation, and GLO maps provides a guide to potential future restoration of water flow pathways, more natural distribution and type of wetlands, and water management within impoundment units that are retained (Fig. 16). Four major creek corridor areas on Monte Vista NWR seem to offer the best options for restoring these creek and wetland conditions (Fig. 32). The first area is at the headwaters of Spring Creek, especially in Unit 19. The second area is the reach of Spring Creek upstream of the confluence with Rock Creek including areas in Units 14, 6, 1, and 7. The third area is in the Spring-Rock Creek confluence area, specifically in Units 3, 4, and 5. The fourth area is the former Cat Creek corridor in Units 16, 17, 22, and 23.

While the natural topography and water flow patterns at Monte Vista NWR are highly altered,

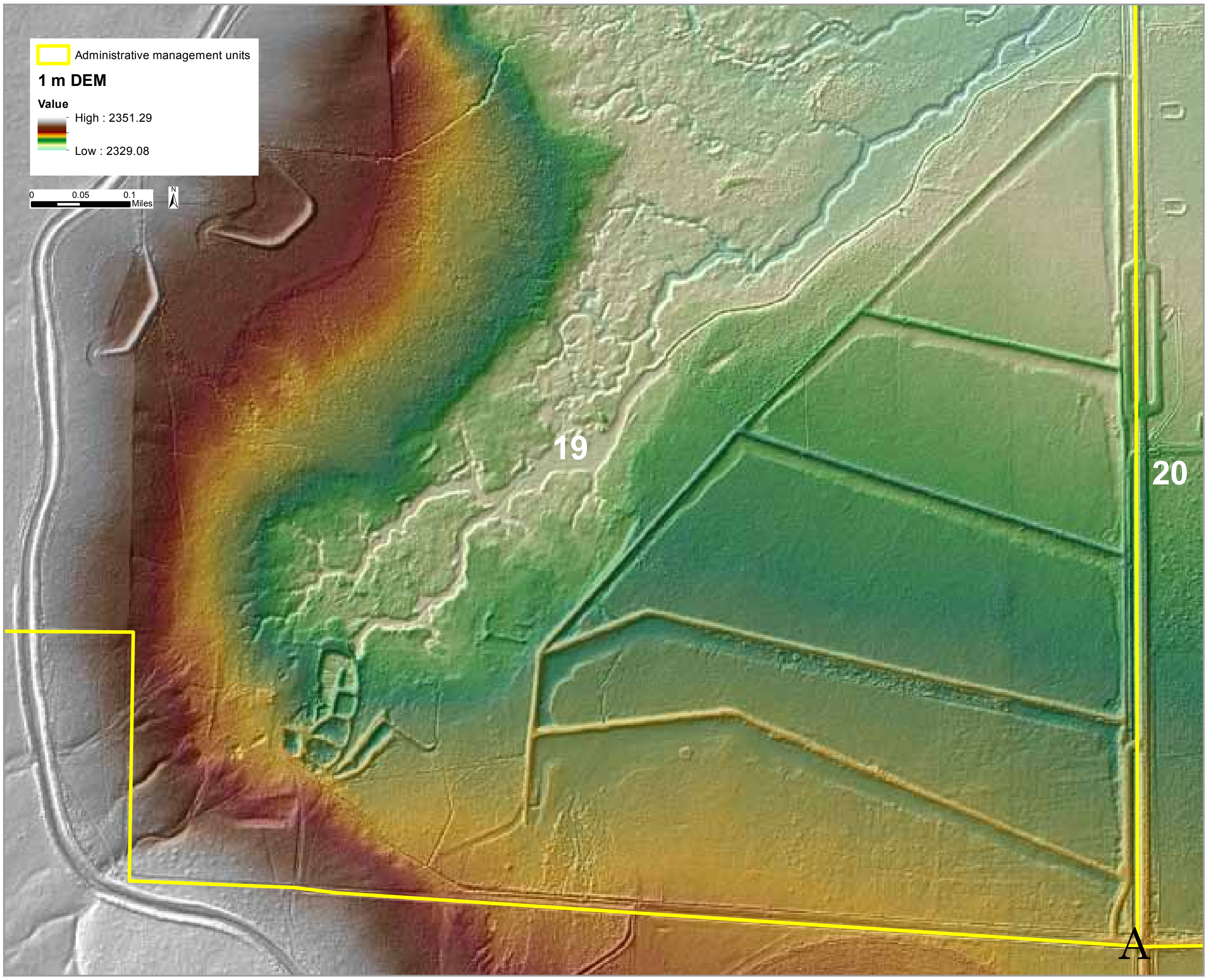


Figure 32. Potential restoration locations to restore flow patterns in former creeks channels on the Monte Vista NWR in relation to elevations changes: a) Spring Creek head in Unit 19 flowing to the northeast, b) Spring Creek prior to its convergence with Rock Creek in Units 14, 6, 7, and 1, c) the confluence area of Spring and Rock Creeks in Units 3, 4, and 5, and d) the old Cat Creek corridor in Units 16, 17, 22, and 23.

some opportunities may be available to modify existing water diversion and control infrastructure to help restore more natural patterns of surface water flow and supply to restored and managed wetland areas. The historic Spring Creek flowed from the southwest in Unit 19 to the northeast through Units 14, 6, 1, and 2 where it joined Rock Creek in Unit 3. Currently many ditches and roads impede natural flow through this system. Removal of infrastructure that impedes this flow and use of existing ditches and structures that will enhance or promote natural flow will help restore the natural hydrologic regime to this drainage. Flow through natural topographic features such as Spring Creek which allows sub-surface flow and dispersal throughout the floodplain can be increased through the correct placement of water-control structures, re-routing of roads to the edges of wet meadows, and the elimination of lead-in and lead-out ditches from water-control structures in wet meadow situations where sheetflow is desired (Zeedyk 1996). Recent LiDAR information (Figs. 8, 9) indicates that the historic creek channels exist at the topographically lowest elevations in relation to adjacent lands. The general landscape on Monte Vista NWR slopes from the west-southwest to east from about 7,732 to 7,586 feet amsl. General flow patterns follow this elevational gradient within the refuge boundaries. Rock Creek flows from north to southeast on the refuge before joining with Spring Creek and flowing along a more easterly course. Cat

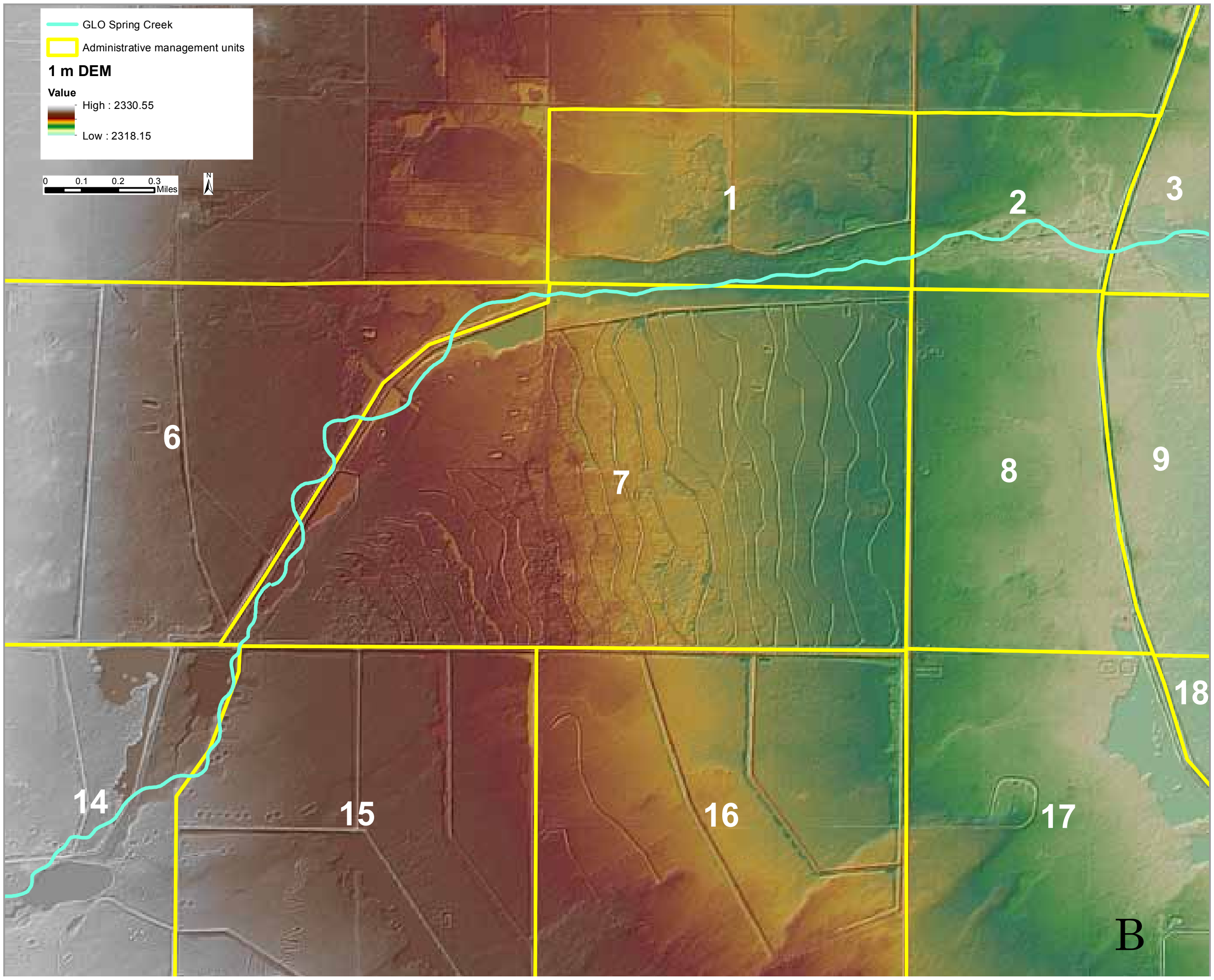


Figure 32 continued. Potential restoration locations to restore flow patterns in former creeks channels on the Monte Vista NWR in relation to elevations changes: a) Spring Creek head in Unit 19 flowing to the northeast, b) Spring Creek prior to its convergence with Rock Creek in Units 14, 6, 7, and 1, c) the confluence area of Spring and Rock Creeks in Units 3, 4, and 5, and d) the old Cat Creek corridor in Units 16, 17, 22, and 23.

Creek flows from the south to the north and east toward the Spring-Rock Creek confluence areas. Where possible, the former creek and natural elevational drainage gradients should be restored.

2. Restore natural topography and promote natural hydrologic regimes to restore at least some areas of historically occurring salt desert shrub and undershrub grassland habitat including its natural heterogeneity of sub-habitat components.

Salt desert shrub was the dominant historical community type present on Monte Vista NWR. As early as the late-1880s, areas of salt desert shrub on Monte Vista NWR were being converted to irrigated pasture and hayland using wells and water diversions. The Monte Vista Canal, which bisects the alluvial fan of Rock Creek, was built during this time, altering the surface and subsurface flow of water across and through this area to the valley floor. Crude early dikes, ditches, drains, and water-control structures were used to move and store water in desired locations, which facilitated removal of remnant shrub vegetation, irrigation of flatter areas, and conversion of salt desert shrub communities to wet meadow and mostly non-native grassland habitats and uses. By the time Monte Vista NWR was established in the early-1950s, considerable parts of the refuge area were in irrigated pasture and hayland. After the refuge

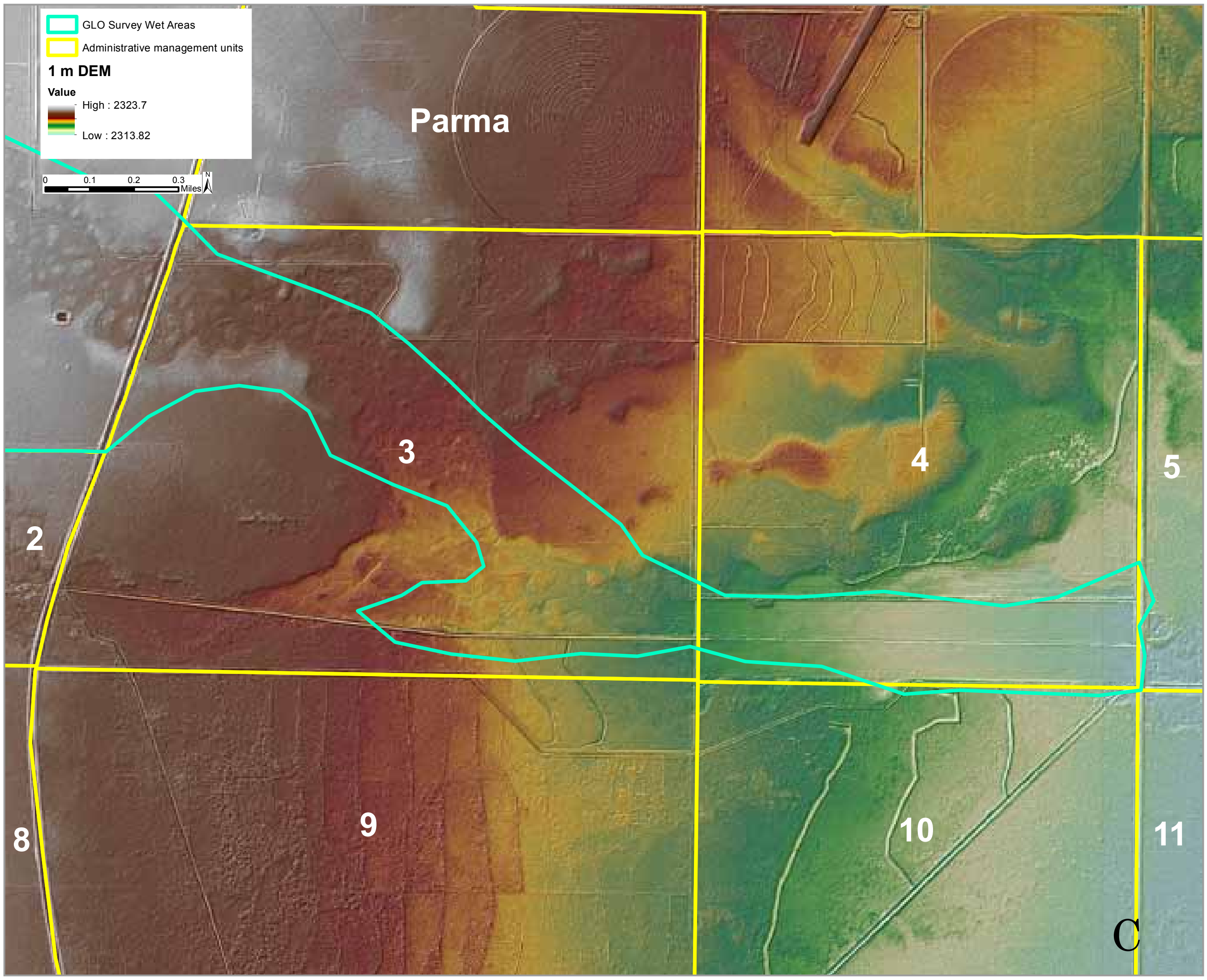


Figure 32 continued. Potential restoration locations to restore flow patterns in former creeks channels on the Monte Vista NWR in relation to elevations changes: a) Spring Creek head in Unit 19 flowing to the northeast, b) Spring Creek prior to its convergence with Rock Creek in Units 14, 6, 7, and 1, c) the confluence area of Spring and Rock Creeks in Units 3, 4, and 5, and d) the old Cat Creek corridor in Units 16, 17, 22, and 23.

was established the extensive development plan for the refuge greatly expanded the dike, ditch, drain, and water-control infrastructure and effectively compartmentalized the refuge into over 80 wetland subunits. These units were constructed mostly with the intent of creating wetlands and irrigated meadows initially for wintering waterfowl, and then eventually almost entirely to support breeding ducks and other waterbirds. The collective effect of these refuge developments and subsequent water management has been the > 50% conversion of native salt desert shrub to irrigated or seasonally flooded habitats. The conversion of former salt desert shrub habitats to meadow, wetland, and crops was done irrespective of soil type or even location on the refuge. This introduction of surface and sub-surface water to former salt desert shrub sites that often did not have soils suited for such irrigation or flooding has frequently increased soil salinity by increasing deposition of evaporative salts, which has in turn caused some sites to become highly alkaline even to the point of creating barren salt flats (SCS 1980). Construction of an efficient water delivery system moved and drained water into and through different units providing surface irrigation directly to sites as well as sub-irrigation indirectly to adjacent sites. Additionally, these former saline soils, now with greater seasonal hydration and salt deposition, have become sites of expansion and colonization of invasive plant species such as tall whitetop (Gardner 2002).

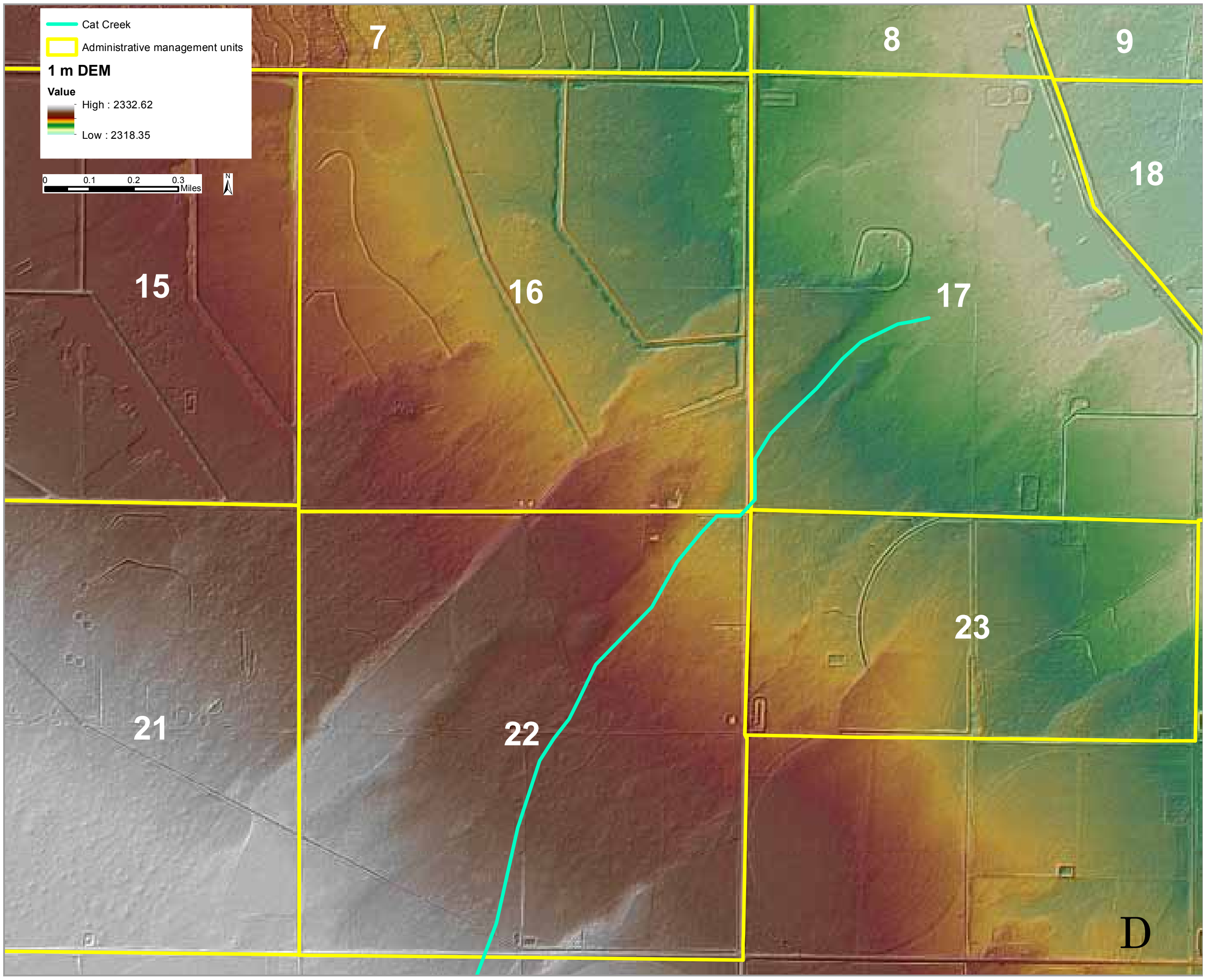


Figure 32 continued. Potential restoration locations to restore flow patterns in former creeks channels on the Monte Vista NWR in relation to elevations changes: a) Spring Creek head in Unit 19 flowing to the northeast, b) Spring Creek prior to its convergence with Rock Creek in Units 14, 6, 7, and 1, c) the confluence area of Spring and Rock Creeks in Units 3, 4, and 5, and d) the old Cat Creek corridor in Units 16, 17, 22, and 23.

The area on Monte Vista NWR that historically (and currently) supported an undershrub-grassland community is restricted to the far west part of the refuge on the bottom foothills of the San Juan Mountains. This foothill area has been altered less than other areas on the refuge, but various topographic developments such as roads, ditches, and dikes exist and native vegetation communities may be less diverse and include increasing amounts of invasive species. Undoubtedly, some of the changes in vegetation composition and distribution are the result of long-term livestock grazing prior to the refuge establishment (Hanson 1929, Fahnestock and Detling 2000, Sayre 2001). Throughout the western U.S., and certainly at the boundaries of the SLV, the loss and alteration of mountain foothill undershrub-grassland habitats has been extensive and contributed to declines in plant and animal species. Species such as fringed sage have become more dominant over time due to disturbances such as grazing and changes in hydrologic regime.

Restoration of these shrublands will require basic changes in water management strategies, removal of levees and ditches, and removal and/or relocation of water-control structures to facilitate sheetflow on Monte Vista NWR. Spring snowmelt throughout the shrub habitat would have naturally pooled water within many small depressions scattered across the area. Overland flow across the hill slopes and subsurface flow through the alluvial fans would have provided additional water resources to depressions throughout the shrub community. Surface flooding would have been of short duration, but provided resources for migrating grassland bird species and some waterbirds and waterfowl. Future management of these habitats at Monte Vista NWR should seek to sustain and restore endemic community composition, structure, and functions on select sites. This will involve allowing surface and subsurface flow across and through the alluvial fan while preventing the impoundment of water for long durations as identified in the first restoration objective stated above.

Given the former expansive distribution of salt desert shrub on Monte Vista NWR it seems desirable to restore at least some former salt desert shrub sites, at least where high soil salinity and higher elevations occur. Additionally, future prospects of more limited surface water availability and lower confined aquifer levels with corresponding decreases in artesian free-flowing wells, suggest that water management on Monte Vista NWR should attempt to prioritize water delivery and storage to former wetland sites and soils, and not attempt to flood non-wetland sites with poor water retention capability and high salinity such as exist in many former salt desert shrub areas. A comparison of current wetland and meadow distribution on the refuge with prior distribution of salt desert shrub offers guidance to the best restoration locations (Figs. 16 and 24).

3. Restore natural disturbance regimes such as herbivory, fire, and drought to promote the health and quality of all habitat types and reduce noxious weeds.

Historical communities on Monte Vista NWR previously were sustained by temporal and spatial dynamics of water amount and distribution, fire, herbivory, and other disturbances caused by seasonal and long-term variation in climatic factors. For example, Rock, Spring, and Cat Creeks meandered across the alluvial fan on Monte Vista NWR and overflowed during wet periods associated with snowmelt in the San Juan Mountains. The creek overflow inundated floodplain depressions, created shallow sheetflow across floodplains, and deposited nutrient-rich sediments and nutrients to these sites. Undoubtedly, at some unknown intervals, flow dynamics were sufficient to cause creek channel migrations, which formed the heterogeneous topography of the creek corridors including wetland depressions, ridges and swales, and natural levees. Overland flow, sedimentation and deposition were driven by climatic variation that affected amount and timing of spring snowmelt and local precipitation events. Consequently the topography, soils, and vegetation communities at Monte Vista NWR were changing at spatially and temporally different scales. Studies conducted on alluvial fans have demonstrated the sometimes drastic changes between the soils and hydrologic characteristics of semi-arid sites occupied by shrubs and interspatial barren areas. Soil structure, organic matter, and infiltration rates vary widely based on microclimate conditions created by shrubland communities (Hooke 2012, Bedford 2008, Bedford and Small 2007). With the development of water diversion infrastructure, increased extraction of groundwater aquifers, construction of roads, and the complete loss of Spring Creek and Cat Creek flows, the natural and historic hydrologic characteristics and disturbance regimes of this area have been eliminated. Also, natural herbivory from elk, deer, and antelope have been altered or eliminated and native ungulate herbivory has been replaced with cattle and sheep grazing. The natural time and duration of disturbance events in SLV wetlands especially occasional drought, fire, and herbivory were important to sustain wetland systems by recycling nutrients and biomass and regenerating communities (Cooper and Severn 2002). Reintroduction of the many important ecological disturbance mechanisms into the Monte Vista NWR system seems important.

It seems unlikely that the natural topography and hydrological dynamics of the creeks historically present on Monte Vista NWR will ever be completed restored, nor will structures such as the Monte Vista or Empire Canals be removed to allow natural surface and subsurface flow across the alluvial fan on the refuge. Consequently, to restore intrinsic values associated with the creeks and alluvial fan habitats, management strategies should seek to emulate natural processes with active water management to provide disturbances that invigorate growth, provide abiotic conditions to promote germination, and supply nutrients to the soil (e.g., Molles et al. 1998, Opperman et al. 2010). Since creek flows have been highly diverted or no longer exist and water management has shifted to more annually consistent and stabilized water regimes, the natural hydrologic flow between creeks and their floodplain has been changed dramatically. Although current vegetation communities on Monte Vista NWR have been greatly altered from former periods and many now are dominated by invasive weeds, implementation of the previous recommendations in conjunction with mimicking natural disturbance regimes, processes, or artificial manipulations will further promote the restoration of wetland and upland habitats on the Monte Vista refuge. The important historical disturbance events in SLV wetlands included creek overbank and backwater flooding, drought, fire, and herbivory; these disturbances helped recycle nutrients and biomass, regenerate communities, and volatilize salts and minerals. Reintroduction of these disturbance mechanisms into the Monte Vista NWR system will be important to restoration of native communities.

Management to provide the above disturbance events will depend on specific management objectives and the appropriate timing, periodicity, intensity, and application of the event. For example, creating conditions to mimic overbank flood events could occur during years with greater spring snowmelt in areas where sheetflow is possible and adequate water delivery systems are in place. For example, a large pulse of water could be directed through the Rock Creek drainage if water-control structures and ditches had the capacity to carry a large volume of water. Likewise, management strategies could variously incorporate fire and herbivory in wetland and grassland areas to help provide a different type of disturbance and nutrient cycling. Each of the different habitats on the refuge will require different rates and types of disturbance to achieve desired results. For example, grazing strategies in wet meadows will differ from those in seasonal wetlands or grasslands.

Natural herbivory by wildlife such as elk that potentially used lands on Monte Vista NWR probably would have been present in large herds for short time intervals as they moved to other sites with available resources, returning when the forage they consumed had recovered. Currently, this type of natural grazing by wildlife species cannot occur. Therefore, mimicking this natural process with cattle or other livestock could help remove invasive weeds and residual vegetation and promote earlier succession plant species. Livestock grazing on Monte Vista NWR has been controversial, but effective grazing strategies can incorporate rest-rotation and short duration/high intensity grazing depending on the objectives, the type of vegetation, and availability of cattle, time, and labor (Sayre 2001). Long-term grazing affects the physiology and morphology of plant species and community structure generally by promoting the growth of shorter stature plants that are less accessible to grazers (Fahnestock and Detling 2000). If livestock grazing is used, strategies should take into consideration plant community structure, phenology, and climatic conditions to promote the growth of desired native plant species. As well, elk and deer herbivory also should be assessed in relation to time of year and differences in patterns when compared with livestock grazing.

Grazing management, coupled with other treatments (e.g. flooding, fire, herbicide, etc), has been shown to assist in weed control, specifically for tall whitetop (Diebboll 1999, Gardner 2002). Rosettes and early stems may be eaten by cattle, although later growth stages are avoided. Thus, timing of grazing will dictate the type of disturbance or effect that cattle would have on this weed. Recently some landowners on the Rio Grande floodplain have changed their grazing management from one or two large pastures where cattle were held for long periods to many smaller pastures with short duration/high intensity grazing. This system appears to have been successful in decreasing invasive weeds such as wild iris (*Iris missouriensis*), Canada thistle, and tall whitetop while also increasing cover, density, diversity and the health of native plant species (pers. comm. Ruth Lewis and Cynthia Villa). A reduction in the extent and density of tall whitetop will improve the health of the wetland resources for waterfowl and waterbirds as well as the nutritional content of forage for cattle or elk grazing on the refuge in subsequent years (Young et al 1995). Selecting specific associations of age classes such as cow/calf pairs or yearlings will impact different plant species based on the time of the year and their unique nutritional needs (Leonard et al 1997).

The use of fire within various habitat types also could help restore native vegetation communities at Monte Vista NWR. Fire removes some or at times all of the vegetation and other organic matter that has built up on the soil surface. This removal and processing of biomass returns nutrients to the system and promotes growth of existing or new plants. Historical frequency of fire in the SLV is not entirely known and likely depended on dynamic climatic conditions, hydroperiods, and habitat type. Wetland areas with historically high water tables probably had a longer period of fire frequency. Fire frequency generally increases away from wetland areas such that the shrub and grassland communities with lower water tables would have a higher fire frequency (Reardon et al. 2005). Some plant species growth response is more positive than others and will depend on the intensity of the fire, season, and potential for subsequent irrigation.

SPECIFIC RECOMMENDATIONS FOR ECOSYSTEM RESTORATION AND MANAGEMENT

1. Restore natural surface water flow pathways and associated hydrological regimes where possible to restore and manage wetlands and wet meadows along Spring, Rock, and Cat Creeks.

Future water management at Monte Vista NWR should consider changes in water-control/diversion infrastructure and refuge management strategies to more closely emulate natural flow patterns, distribution, and seasonal/long-term dynamics of surface and subsurface water to reinstate appropriate historical distribution of communities, especially wetland and meadow types, improve native plant species diversity and productivity, reduce alkali concentrations, and increase water efficiency. Specific management actions to consider include:

- Evaluate opportunities to restore topography and natural water flow patterns through the historically intermittent Cat Creek drainage. Allow for natural drying of the creek drainage during dry years. Remove or modify levees and water-control structures in Units 16, 17, 18, 22, and 23 (excepting the large Empire Canal, which is not controlled by the USFWS) to more closely mimic the historic flow of water through this system (Fig. 33a). Currently a large east-west levee bisects the historical Cat Creek channel in Unit 22 and several levees exist in Unit 18 on the east side of the Empire Canal, which lie in the historic drainage path of Cat Creek. If possible, future restoration of this drainage could discuss possible water-control infrastructure that would allow water to pass through the Empire Canal on very wet years.
- Remove the ring dikes/ponds that occur within the Cat Creek drainage.
- Restore flow to the natural Spring and Rock Creek drainages by removing or modifying the levees, ditches, and water-control structures that impede flow and that are not useful for other strategic water diversion and management. This evaluation of ditch and levee modification will require detailed future hydrological and topography analyses and engineering, which is beyond the scope of this report. For example, some ditches and water-control structures may aid in mimicking the natural distribution of this water through the various units. While State Highway 15, County Road 3E, and the Empire Canal probably cannot be removed or extensively modified to allow a more complete restoration of the Spring-Rock Creek drainage system, some potential does exist to provide a more natural flow of water in these creek corridors. For example, current infrastructure in Units 19, 14, 6, 7, 1, 2, 3, 9, 4, 5, and 11 (listed in downstream flow progression) contain portions of these historic channels and obstructions to natural flow patterns and pathways should be removed where possible (Fig. 33b,c). Removal of levees which bisect or parallel these drainage patterns is important to promote natural surface and subsurface flow through this system.
- Evaluate options to use and/or modify existing water delivery infrastructure to reestablish overland sheetflow in wet meadows. Existing water-control structures that are located too high or low in a levee can prevent natural flow and distribution to wet meadow areas. All existing water-control structures in former wet meadow and wetland habitats should be evaluated for invert-discharge elevation setting and location to achieve restoration options.
- Restrict prolonged flooding and PEM-type wetlands to areas with Vastine soils types along the former Spring and Rock Creek drainage corridors located predominately in Units 1-5 and 11 (see Fig. 7). Manage water regimes in these wetlands to emulate seasonal inputs of water and flooding duration. While an original objective of the refuge was to provide wintering habitat for waterfowl, the inherent natural climate and hydrology at Monte Vista NWR rarely caused open surface water to be present except in creek channels.
- Manage water regimes in former wet meadow communities on Arcasco, Alamosa, Mishak, Torsido, and Typic Fluvaquents soil types in Units 3, 6, 9, 13, 17, 22, and 23 with short duration spring and early summer flooding. Subsurface flows in wet meadows adjacent to

historic creek channels may be accomplished through a combination of restoring flows in the creek channel and modification of water-control structure placement in roads and levees that increase the volume of flow, rate, and dispersal over time (USDA 1996). Use of multiple raised culvert arrays that incorporate one large capacity squash pipe for creek flows associated with multiple smaller pipes spread out across the floodplain to disperse flows mimicking overbank events have been successful (USDA 1996).

- Vary annual flooding regimes of wetland units among years to emulate periods of natural drought or more extended flooding.
- Remove wetland sub-units that are located on sites historically in saline salt desert shrub habitats (see discussion under #2 below about specific salt desert shrub restoration options).
- Prevent conversion of former wet meadow and salt desert areas to seasonal or semi-permanent wetlands through prolonged flooding, for example in Units 5 and 11. Such conversion using prolonged flooding regimes facilitates expansion of Baltic rush and seasonal wetland vegetation in soils that are unsuited to these wetter states. Diversion and impoundment of water in these upland areas carries whitetop seeds and provides conditions for establishment of the weed in these areas as roots can then grow in subsequent years to several meters dependent upon depth of the water table.
- Control invasive plant species in wetlands in part through water management mimicking a natural hydrologic regime in appropriate soils.

2. Restore natural topography and promote natural hydrologic regimes to restore at least some areas of historically occurring salt desert shrub and undershrub grassland habitat including its natural heterogeneity of sub-habitat components.

Salt desert shrub habitats historically dominated the large alluvial fan surface on Monte Vista NWR. Soil conditions and hydrologic characteristics associated with this community now have been altered greatly. Nonetheless, restoration of natural hydrologic regimes in areas that were historically occupied by salt desert shrub habitats is possible. Salt desert shrub habitat still exists in some areas on the refuge including large contiguous tracts in Units 5, 10, and 11. Remnants of this shrubland also exist in smaller patches throughout the refuge. The areas of historical, and current, undershrub-grassland habitat on Monte Vista NWR was/is restricted to the lower foothill/alluvial fan area in the far west part of the refuge. Specific management actions that could assist restoration of salt desert shrub habitats include:

- Target restoration of salt desert shrub to its former distribution especially in areas where some shrubland still exists. Units 4, 8, 16, 20, and 21 have some remnant stands of shrubland in addition to large areas of tall whitetop invasion. Targeting these areas provides a core area of native vegetation, seed source, and soils adapted for further shrub expansion. With a return of a natural hydrologic regime, native plant species should be favored rather than invasives. Levees within each of these units bisect historic shrublands and should be removed or modified because they are conduits for invasive weed seed dispersal, prevent natural sheetflow, and promote ponding of water in soils that are adapted for shrublands.
- Evaluate units that lie entirely within historic shrublands that currently are managed for short emergent wetlands. Remove water-control infrastructure and restore natural topography and overland surface sheetflow capability to these areas. For example, Unit 7 historically contained saline soils and shrub habitats, especially in the eastern side of the unit. Ideally, most, if not all, of the closely spaced contour levees in Unit 7 should be removed and the unit restored to salt desert shrub habitats. The Spring Creek historic channel lies directly adjacent and north of this unit and levees and roads that prevent natural flooding and sub-irrigation of the north portion of this unit should be removed or modified. The presence of approximately 26 parallel, north-south running levees have completely altered the natural flow of water and converted shrublands to short emergent habitat that is being invaded by tall whitetop from the east and west sides of Unit 7 (Fig. 33b).

- Remove all ring-dikes and decommission small intermittent flow artesian wells throughout the refuge. Most of the ring-dike sites occur within shrubland areas and in the past the small artificial ponds created by the ring-dikes concentrated birds and helped promote diseases (refuge annual narratives). Currently the ring-dikes prevent sheetflow, act as a drain to adjacent areas which are of slightly higher elevation, increase evaporative salt accumulations, and are sources of invasive weed expansion.

- Restore a natural hydrologic regime in shrubland areas by timing irrigation/flooding to a more natural spring runoff that increases the water table and sub-irrigates adjacent shrublands which may discharge in historic temporary wetland areas. Shrublands in Units 19, 14, 6, 7, 3, and 4 that occur adjacent to the historic Spring Creek and the confluence with Rock Creek will benefit from this type of shorter duration, spring hydrologic regime.

- Protect foothill areas from additional physical alteration caused by roads, ditches, and other potential developments. The Monte Vista Canal and parallel road have prevented natural hydrologic flow in Units 13 and 19 (Fig. 19). Creation of large levees, borrow ditches, and water delivery infrastructure

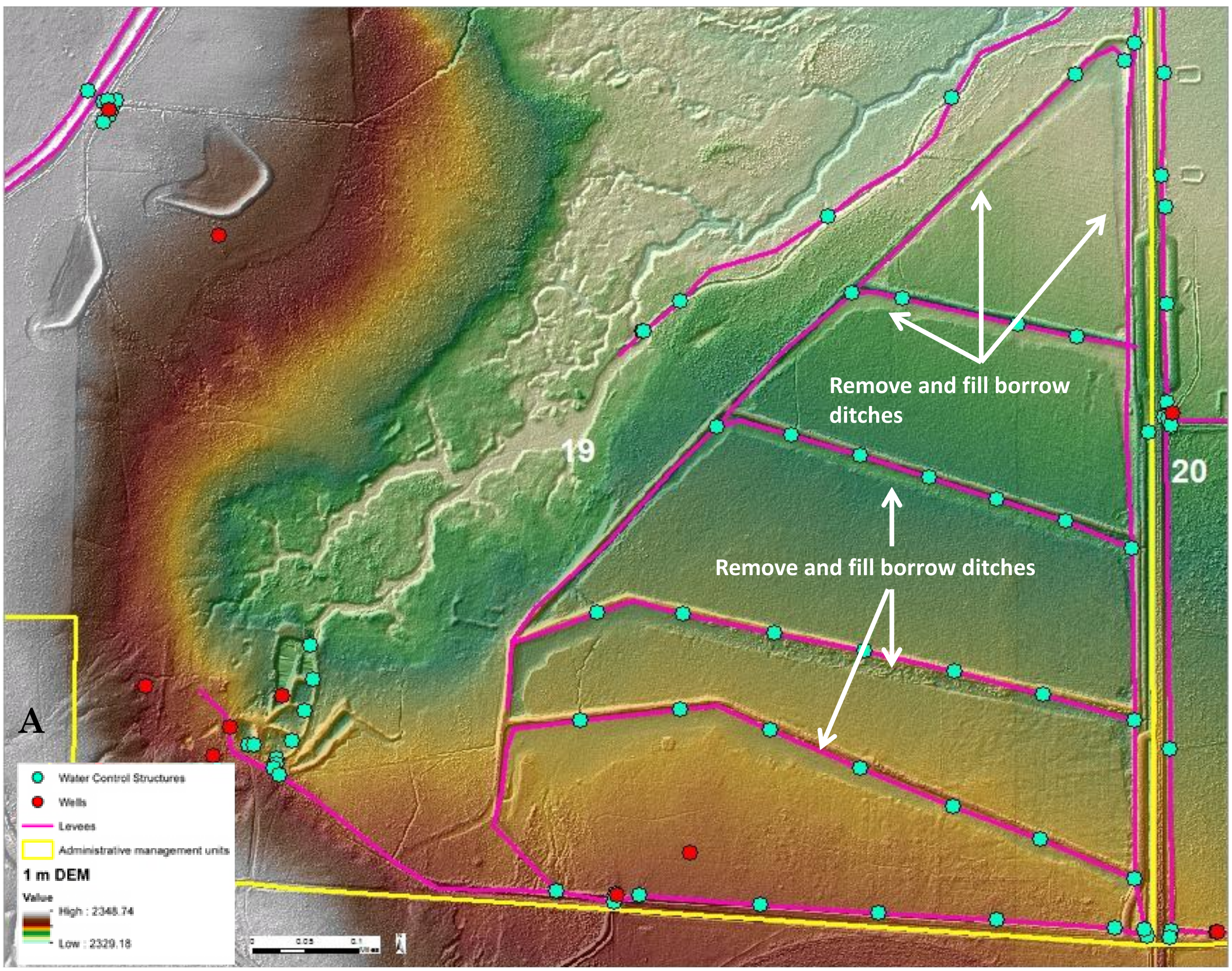


Figure 33a. Potential restoration in Unit 19 indicating elevation gradients, location of water-control structures, and the extent of spring flooding based on typical water management activities. Potential restoration options could include filling deeper borrow areas near dikes with soil to reduce the water required to provide suitable habitat for migrating sandhill cranes. Doing so would increase wetland acres while reducing overall water use in the unit.

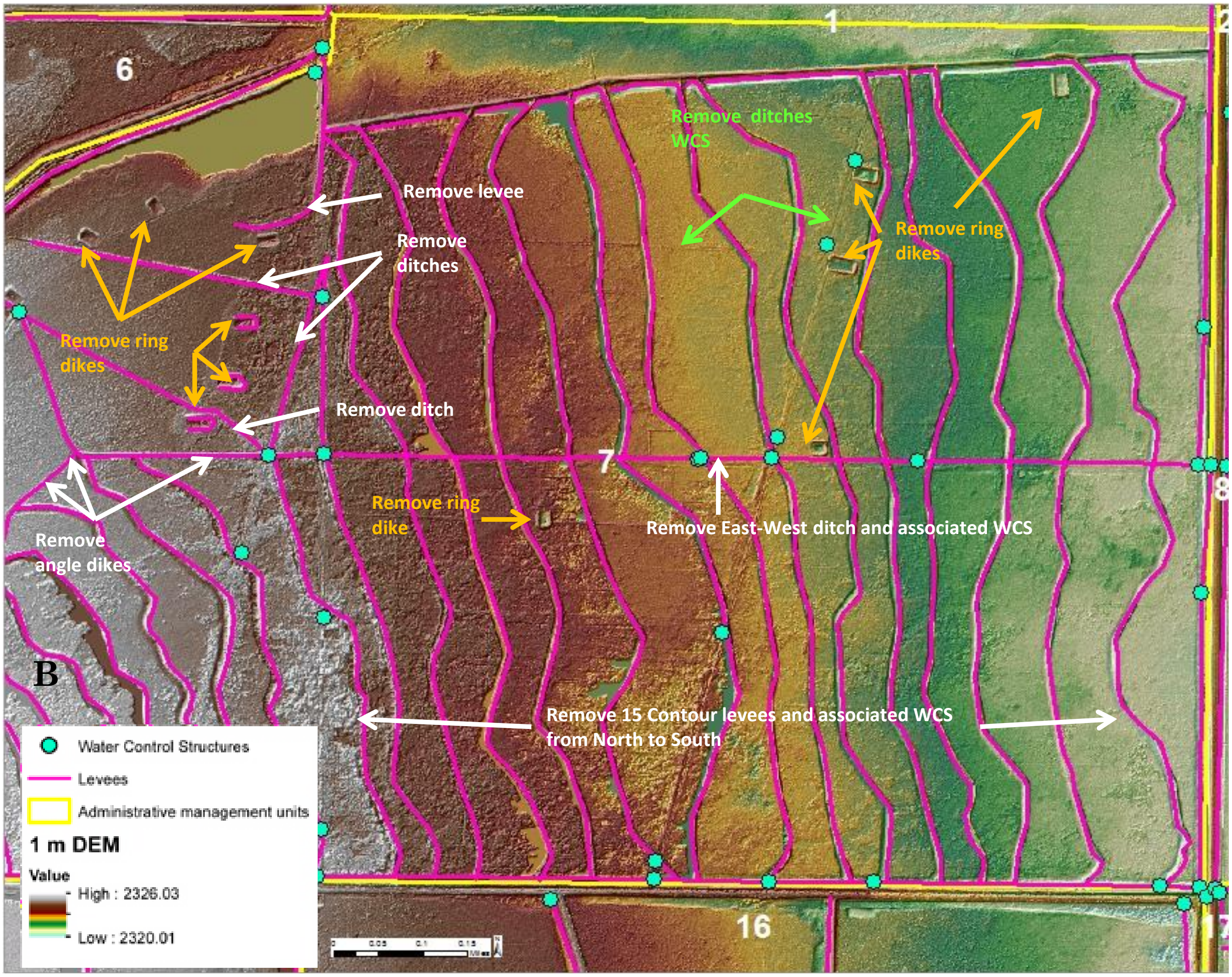


Figure 33b. Potential restoration in Unit 7 indicating locations to remove levees, ring dikes, ditches, and water control structures in order to promote the growth of native vegetation and restore natural hydrologic conditions. Unit 7 was historically dominated by salt desert shrub as indicated by soils, remnant native vegetation communities, and the invasion of weeds. The eastern third contains the most saline soils and represents an area of continued invasive weed expansion such as tall whitetop. Water historically may have overflowed from the creek and sub-irrigated some of these shrublands from the north, however prolonged flooding, tall emergent, and back flooding from east to west was not apparent.

within an historic shrubland in the south and east portions of Unit 19 have converted this area to short emergent habitat with large stands of tall whitetop (Unit 22 and 27). Further, the actual flood capacity area in Unit 19 created by the parallel angle dikes is very limited and does not justify the infrastructure, cost of water diversion and storage, or conversion of former salt desert shrub to a non-natural wetland state (Fig. 33a). The historic drainage of Spring Creek flows from the southwest corner of Unit 19 to the northeast and is north of the current impoundments. Complete restoration of Unit 19 may be complicated by desires to have surface water and public viewing sites along Highway 15, but promoting more natural flow patterns and flooding/drying regimes from southwest to northeast in Unit 19 by removing or modifying levees and borrow areas would help mimic a more natural hydrologic regime along Spring Creek and promote a more native composition of vegetation.

- Remove roads that promote impoundment of water, restore sheetflow, and emulate annual drought conditions throughout shrublands. Some roads exist that do not contain water-

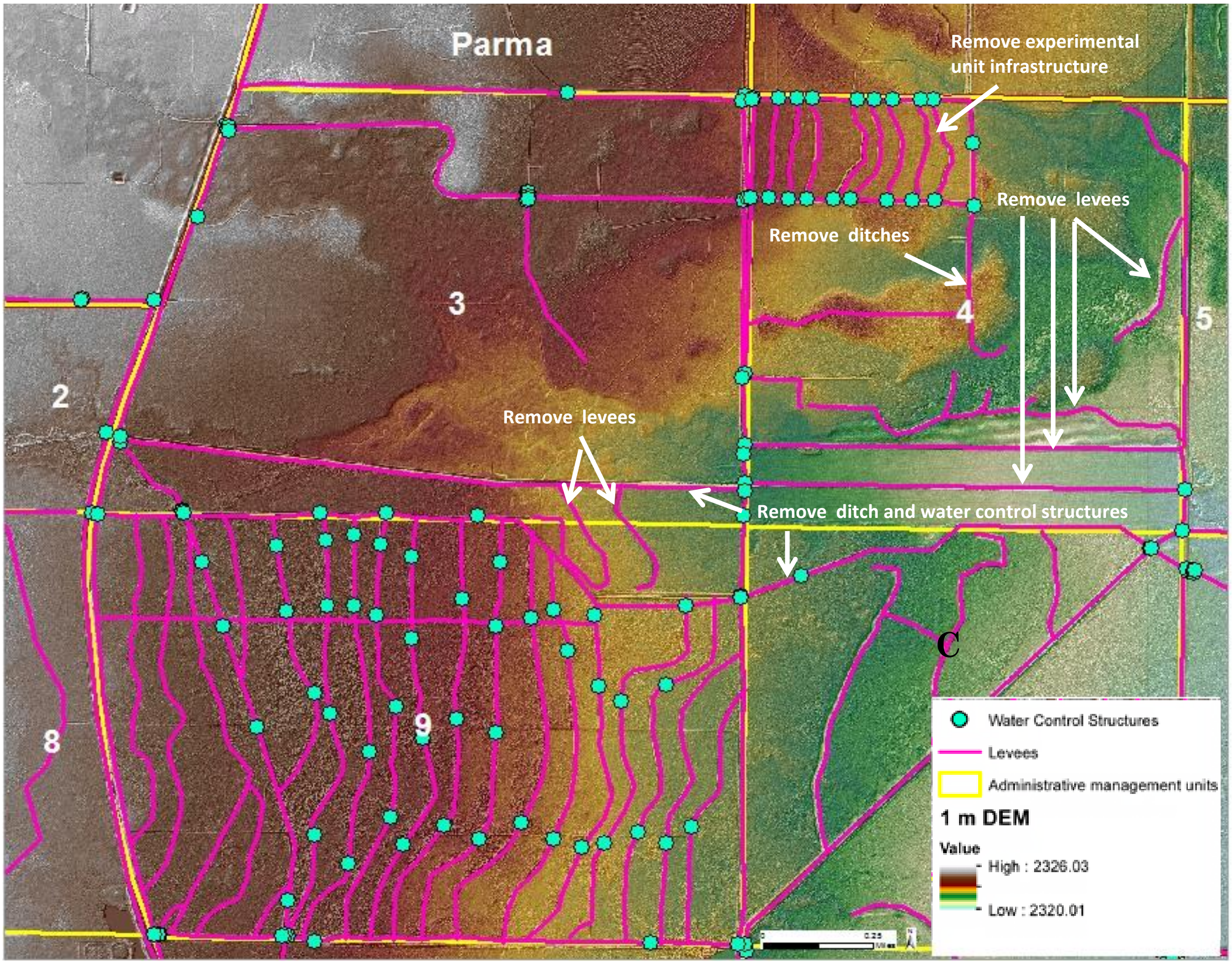


Figure 33c. Potential restoration at the confluence of Spring and Rock Creeks in Units 3, 4, and 9 indicating locations to remove levees, ditches, and water-control structures in order to promote the growth of native vegetation and restore natural hydrologic conditions. The confluence area represents the largest extent of wetland habitat historically present within refuge boundaries as indicated by soils, remnant native vegetation communities, and the GLO map. Water historically may have overflowed from the creek and sub-irrigated some of the areas to the north and south of the creek area.

control infrastructure and serve to impound water in Units 14, 21, and 24. Removal of these existing roads in former shrublands will help to improve the natural hydrology of the area and prevent impoundment of water.

- Prevent impounding water due to water delivery infrastructure which is poorly placed (vertical or horizontal), lacks the capacity to transfer water flows, or has become unusable in shrubland areas. Some sheetflow may be appropriate in late winter/early spring but should be avoided in late spring/early summer to avoid killing woody species.

- Remove water-control structures and levees in former shrublands that are no longer utilized. For example, Unit 4 historically contained wet meadow adjacent to the Rock Creek drainage and salt desert shrub in higher elevations (Fig. 16). Currently large monotypic stands of tall whitetop occur throughout the unit (Fig. 26) and smaller patches of whitetop occur in other areas. The northwest corner of Unit 4 contains approximately 20 water-control structures tied to a series of levees in former shrub habitat. Other levees throughout this unit bisect shrublands and historic drainages

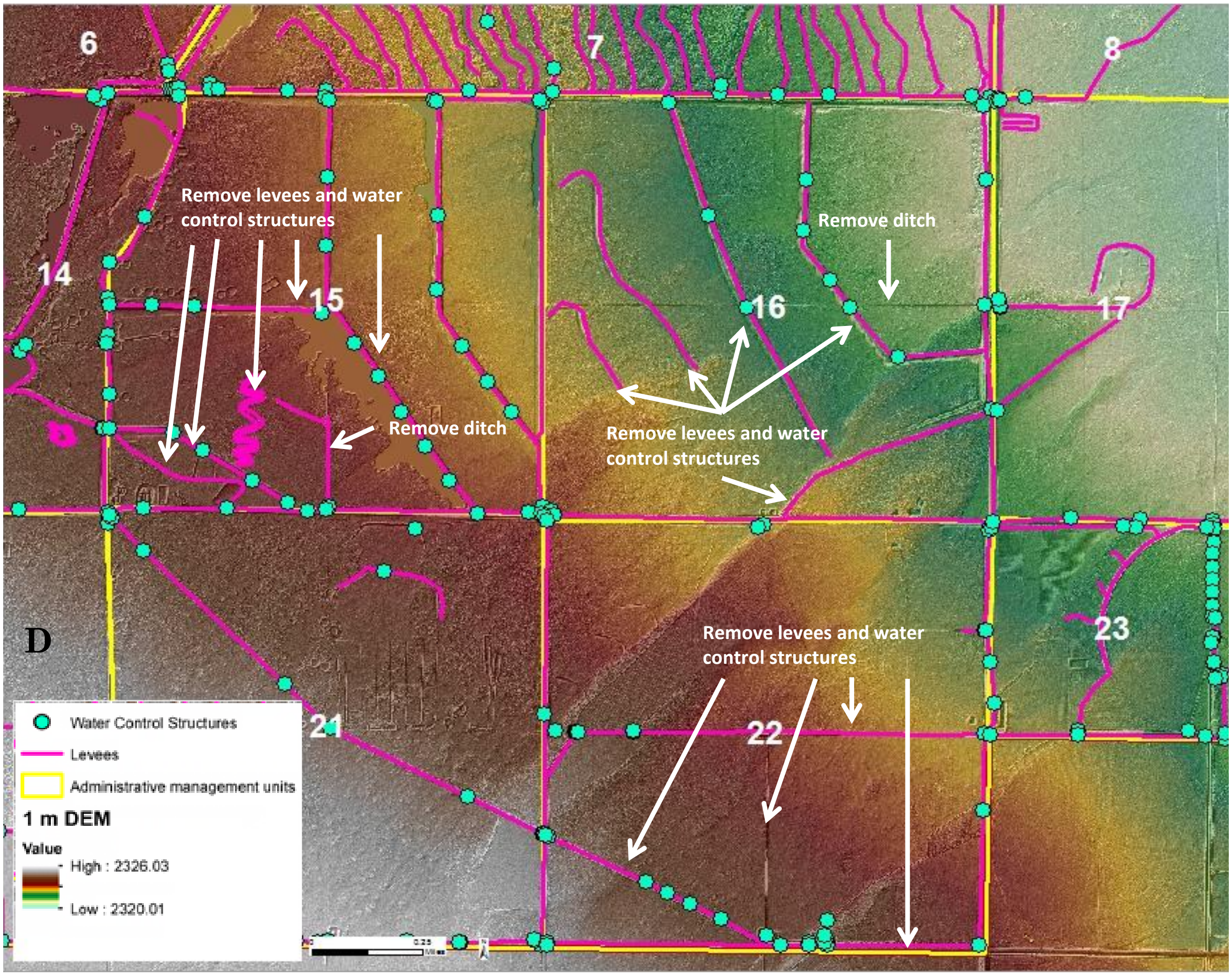


Figure 33d. Potential restoration at the confluence of the terminal portion of Cat Creek in Units 21, 22, and 16 indicating locations to remove levees, ditches, and water-control structures in order to promote the growth of native vegetation and restore natural hydrologic conditions. This area, including Unit 15, was historically a heterogeneous assemblage of wet meadow, salt desert shrub, and saline salt desert shrub as indicated by soils, remnant native vegetation communities, and historical maps and accounts. Tall whitetop is currently a dominant species throughout these units and the Cat Creek corridor. Water historically may have overflowed from the creek and sub-irrigated some of the areas to the east and west of the creek area for short periods of time.

and artificially impound water creating conditions favorable for the expansion of tall whitetop.

3. ***Restore natural disturbance regimes such as herbivory, fire, and drought to promote the health and quality of all habitat types and reduce noxious weeds.***

- Investigate further the historical natural occurrence of disturbance events such as fire and herbivory in the SLV and at Monte Vista NWR to understand the potential of using these techniques to manage vegetation or recover natural processes (such as recycling nutrients with rodent herbivory, volatization of salts and other elemental constituents through drought and fire, creation of plant regeneration sites, etc.). As an example of data uncertainty, yet management potential, the natural dynamics of historical frequency and intensity of wildfires in the SLV is not specifically known for each of the habitat types but areas with lower water tables (e.g., foothill grasslands) typically have a higher frequency of fire occurrence and could be managed as such.

- If fire can be used in grasslands, attempt late winter burns to remove residual vegetation and allow new growth of vegetation in the spring. Winter burning will allow for greater coverage of herbicide application on target invasive weeds in the summer. Spring, summer, and fall burns also may be applicable depending on the species to be controlled or promoted. For example, warm and cold season grasses typically require and respond more positively to fire prescription during different seasons e.g. spring, summer, fall, based on their respective phenologies.

- Consider managing seasonal wetland and wet meadow communities with some type of vegetation removal and recycling including fire, grazing, mowing/haying, etc. in combination with changes in water management. Promote a grazing management strategy that incorporates knowledge of different plant's life history characteristics to allow for growth and recovery in relation to the current climatic conditions. Grasses, rushes, and sedges will recover at different rates depending on the season and phenology of the plant. Therefore stocking rates and timing should be adjusted based on the response of plants relative to the management objectives.

- Mowing or haying may be done to mimic natural herbivory if grazing is not an option. Mowing of habitats that will be flooded will allow residual vegetation to provide the necessary structure for invertebrate communities. Removal of the residual structure may increase soil temperatures and promote the growth of other species. Both strategies may be utilized to help prevent the expansion of tall whitetop and Canada thistle, reduce cover and density, and allow other native species to out-compete the weed.

- Allow (or encourage) natural overbank flood events to occur by providing creeks access to their historic floodplains. Water control structures may need to be moved or replaced in order to facilitate these events (see previous recommendations).

- Promote drought conditions in shrublands on an annual basis to promote historic abiotic conditions which created micro-habitats and unique hydrologic regimes between soils occupied by shrubs and barren areas. These conditions may promote wind erosion which could help restore topography, soil chemistry, and vegetation communities. Further, small mammals may re-populate these areas and promote the microsite conditions that historically existed by burrowing and aerating the soil beneath shrubs (Bedford 2008).

- Promote drought conditions in current tall emergent wetlands that will be restored to seasonal or wet meadow habitat types in the floodplain of Spring and Rock Creeks, e.g. Units 14, 6, 7, etc. Fire, mowing, and haying can be used to remove residual vegetation and help set back succession to promote short emergent species that will thrive in a more spring/seasonal hydrologic regime.

- Control invasive species, such as tall whitetop, Canada thistle, and hoary cress utilizing a combination of treatments including drought, mowing, targeted grazing, and herbicide applications. Sites with some residual native species and potential to provide natural hydrologic regimes will probably have the greatest chance of success in terms of reducing invasive plants and restoring native communities (Baker et al 1997). Encouraging core sites such as Units 5 and 10 and 11 south of the Bowen Drain will provide a starting point from which weed control may expand annually by developing a large area with small amounts of weeds.

MONITORING AND EVALUATION

The current understanding of the SLV and the Monte Vista NWR ecosystem has been enhanced by documentation of system attributes and management actions (such as in former annual narratives of the refuge) and past monitoring and evaluation studies of vegetation and animal communities, water quality and quantity, and specific management actions. Future management of the system would benefit from continuing key monitoring studies and directed studies as needed (Paveglio and Taylor 2010). Monitoring will be determined primarily by refuge objectives, but some measures should be collected that facilitate evaluation of how factors related to ecosystem structure and function are changing, regardless of whether the restoration and management options identified in this report are undertaken. Ultimately, the success in restoring and sustaining communities and ecosystem functions and values at Monte Vista NWR will depend on how well the physical integrity and hydrological processes that affect the refuge can be restored, maintained, and emulated by management actions. The availability of future water amounts, timing, and type (groundwater vs. surface water source) is a major factor that must be carefully considered because uncertainty exists about the future of some important water issues and the ability of the USFWS to influence appropriate hydrologic changes that are not completely under the control of the USFWS. Also, specific techniques for certain management actions, such as controlling and reducing introduced plant species and the efficacy of restoring native composition and integrity of salt desert shrub habitats are not entirely known.

Whatever future management actions occur on Monte Vista NWR, activities should be done in an adaptive management framework where: 1) predictions about community response and water issues are made (e.g., increased diversity and vigor of wet meadow species) relative to specific management actions (e.g., restoration of seasonal sheetwater flow) in specific locations or communities (e.g., Torsido clay loam soils) followed by 2) monitoring to evaluate ecosystem responses to the action. Information and monitoring needs for Monte Vista NWR related to the hydrogeomorphic information evaluated in this report are identified below:

GROUND AND SURFACE WATER QUALITY AND QUANTITY

The recently completed Water Resources Inventory and Analysis (WRIA) for Monte Vista NWR identified several important future monitoring and information needs related to water. These and other needs include:

- Protect water rights for the refuge through careful monitoring and reporting of water use and ecosystem benefits. This will include updating well-meter calibrations.
- Evaluate potential alternatives to existing water sources and supplies to augment water supplies in the advent of decreased availability of some sources.
- Complete inventories of all water management infrastructure including water-control structure size, type, location, direction of flow, etc. to develop a refuge-wide water use management model.
- Conduct routine monitoring of water quality and contaminant issues in relation to water source and routing. Regular monitoring of surface, ground, and soil salinity if key reference locations related to HGM-determined communities should be established.

- Establish water flow metering at key points on the refuge.
- Monitor salinity levels in a variety of wetland types in relation to source of water, duration and depth of flooding, and seasonal flooding/drying regimes.
- Continue to participate in SLV water monitoring and management activities and determine potential effect of various climate change scenarios.

RESTORING NATURAL WATER FLOW PATTERNS, AND WATER REGIMES

This report identifies several potential physical and management changes that could help restore some more natural topography, water flow, and flooding/drying dynamics in managed wetlands. These changes include restoring at least some more natural sheetflow of water through natural drainages and across former wet meadow areas and managing units (that are retained) for more natural seasonal flooding regimes. Further, restoring inter-annual dynamics of flooding and at least partial drying of the impoundments managed for semi-permanent water regimes and persistent emergent vegetation is desired. The following monitoring will be important to understanding effects of these changes if implemented:

- Map locations of levees, ditches, and water-control structures that are removed or modified.
- Document how water moves across and infiltrates former wet meadow areas and soil types.
- Establish groundwater monitoring to document changes in subsurface flows as hydrology is restored to shrublands and wet meadows.
- Evaluate surface and groundwater interactions and flow throughout historic creeks and floodplains.
- Document changes in the water table in shrublands and extent, duration, and periodicity of sheetflow in these areas.
- Document surface and subsurface flow patterns across the alluvial fan.

LONG-TERM CHANGES IN VEGETATION AND ANIMAL COMMUNITIES

The availability of historic vegetation information coupled with regularly documenting changes in general and specific vegetation communities is extremely important to understand the long-term changes and management effects on Monte Vista NWR. Also, regular monitoring of at least some select animal species or groups helps define the capability of the Monte Vista NWR ecosystem to supply key resources to, and meet annual cycle requirement of, animals that use the refuge and regional area. Important survey/monitoring needs include:

- Detailed inventory and mapping of plant species composition, distribution, productivity, and coverage in all habitats. In areas where water-control structures are removed or modified, vegetation should be mapped prior to modification/removal to evaluate subsequent changes.
- Cover, density, and diversity, including expansion and contraction rates, of invasive species before and after control treatments.
- Abundance, chronology of use, survival, and reproduction of key waterbird and neotropical migrant songbirds including dabbling ducks, sandhill cranes, white-faced ibis, etc. For example, monitor use of foraging areas for white-faced ibis before and after changes are made to water management infrastructure.
- Rates and occurrence of fire, grazing, and mechanical disturbances in wetlands and grasslands in relation to vegetation response.
- Vegetation response to grazing strategies including the rate, timing, and intensity of grazing taking into account the seasonality and climatic conditions.
- Occurrence, distribution, and abundance of amphibians and reptiles such as the northern leopard frog in relation to all life cycle events. Document bull frog (*Lithobates catesbeianus*) presence in persistent emergent wetlands prior to and after changes in water management.
- Presence of invertebrate communities in existing wetlands with follow-up sampling in subsequent years to determine changes in abundance related to water regimes.

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